Appendix A Proposal Abstracts

LC-01 Group Augmented Abstract

Agricultural Colonization in the Ecuadorian Amazon: Population, Biophysical, and Geographical Factors Affecting Land Use/Land Cover Change and Landscape Structure

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Objectives

We propose studies in two theme areas of LBA Ecology: land use and land cover change (LULC), and Carbon Storage and Exchange. This will involve examining the human and biophysical dimensions of LULC in the Ecuadorian Amazon associated with high rates of spontaneous colonization (land clearing) by agricultural settlers migrating into the region since the early 1970s. A satellite time series from the 1970s through 1998, along with GIS thematic coverage of biophysical gradients and geographical accessibility, will be linked to data collected on the ground from a unique scientific sample of geo-referenced farm household plots and nearby communities. Data will be collected from the latter in 1998-99 on the same settler plots surveyed in 1990 to measure LULC over time in detail, and to relate it to population and socioeconomic characteristics of settler households. Image processing to characterize LULC and spatial analyses of landscape structure will be used to assess the rate and nature of LULC and to model the effects of LULC, secondary plant succession, and land fragmentation on carbon budgets and assimilation rates for landscape strata and the study area as a whole. Statistical models will be used to estimate the demographic, socioeconomic, biophysical, and geographic determinants of LULC at the farm and community levels. Agricultural extensification and intensification will be documented at the three spatial scales of the farm plot, the sector or community of which it is a part, and the region.
The project will be carried out in an area which is in the Amazon headwaters, one characterized by extraordinary biodiversity, undergoing more rapid colonization and deforestation than elsewhere in the Western Amazon due to its being opened following the discovery of large oil deposits. A scientifically representative sample of 480 household settler plots interviewed in 1990 will be re-visited in 1998 to provide a unique, representative assessment of changes in LULC over time, including land extensification, land intensification (and sustainability of agricultural technology), land abandonment, and secondary succession, with implications for the carbon budget. Lessons will be learned about the process of LULC and its implications for carbon budgets as well as policies to promote to improve sustainability of methods and forest preservation.

Research Team Responsibilities

- Richard Bilsborrow: LULC, survey design and data collection, statistical modeling
- Stephen Walsh: LULC and carbon measurements, GIS imagery
- Aaron Moody: LULC and carbon measurement, GIS imagery, statistical modeling and projections
- Laura Murphy: LULC, data collection and processing, statistical estimation
- Lawrence Band: carbon measurements
- Danilo Silva: LULC, data collection and GIS imagery
- Gustavo Rodriguez, Quito, Ecuador: LULC, data collection, cleaning, analysis

Project Site

The central part of the two northern Ecuadorian Amazon provinces of Napo and Sucumbios, the principal area of oil discovery, road building, and in-migration in Ecuador since the 1970s.

Activities

(This assumes we can begin field activities in mid-1998 at the latest.)

- GIS: Acquire remote sensing images, historical and current base maps and maps of roads and towns and infrastructure (to the extent possible, such as of schools, health clinics, oil camps and pumping stations and

pipelines, etc.), hydrography, topography, aerial photography. Order GPS units and load software onto laptops for data collection and correction. Preprocessing of satellite data and digitization of map data into ARC/INFO format. Train Ecociencia (Ecuador) staff in use of GPS devices and GIS. 1998
- Household and Community Surveys. Prepare/revise household- and community-level questionnaires. Hire and train interviewers in Ecuador. Conduct pretests of questionnaires and of GPS devices and calibrate measures of land use with satellite imagery. Procure equipment for fieldwork. Conduct field surveys. Clean and process survey data. 1998 to mid-1999.
- LULC classification validation using both ground/survey and satellite data. 1999
- Carbon storage and sequestration. Estimate biomass and leaf area. Assess pattern metrics and landscape structure associated with fragmentation. Estimate carbon dynamics associated with LULC. 1999-2000
- Assess extent of extensification and intensification and determinants thereof. Conduct multivariate and multi-level analyses of LULC, derive policy implications, and prepare papers for presentation at conferences, journal submission and a book in both English and Spanish. 1999-2000
- Transfer of data and technology to Ecuador and other LBA investigators. 2000

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LC-02 Group Augmented Abstract

Land-Cover/Land-Use Change and Carbon Dynamics in an Expanding Frontier in Western Amazonia: Acre, Brazil

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Objectives

The proposed research will focus on land-cover change, its quantification and forcing functions, and on natural forest dynamics in the State of Acre, Brazil. Acre is one of the prime frontiers for evaluating current trends of deforestation and logging. This region already has large-scale colonization projects, logging activities, and extensive cattle ranching, and has a population growing at 3%/year, one of the highest rates in Amazonia.

In addition, the region has unique characteristics for comparative studies of degradation with extensive areas of eutrophic soils intermingled with nutrient-poor oxisols and ultisols. The area has some of the most innovative alternative land-uses in Amazonia -1.4 million ha of extractive reserves - that maintain forest ecosystem function and provide income to forest residents. Acre also has about half of the 18 million ha of bamboo-dominated forests of western Amazonia. The expansion and contraction of these low-biomass forests have strong implications for the carbon dynamics of the region. Uncertainties in the rate of deforestation and in the biomass of primary forests currently limit estimates of anthropogenic modifications of the Amazonian carbon budget. Rates of deforestation based on similar data sets differed by a factor of 2 in Acre during the late 1980s and estimates of biomass for primary and secondary forests in Amazonia vary by 30% or more.

We will use multi-temporal satellite imagery extensive and ground truthing to determine the rates, patterns, and causes of land-cover change during the past decade, at various scales, concentrating in eastern Acre, and will compare this with other sites on the western LBA transect. Geo-referenced permanent plots in different forest types will be used to determine forest biomass, growth and mortality rates, as well as serve as calibration sites for new satellites. Fire frequency and distribution will be determined with ground truthing to verify AVHRR hot pixel data. We plan to participate in parallel studies at primary and secondary tower sites along the LBA western transect. In collaboration with other researchers, we will analyze the fire susceptibility of different forest types, including secondary forests. We will use high-resolution remote sensing to map logging activities, natural clearings, and forest types. Multi-temporal imagery will be used to estimate the dynamics of the bamboo-dominated forests in the region.

These detailed studies will be compared with the regional data produced by other collaborators to estimate precision and accuracy of basin-wide deforestation and burning rates. These data will be stratified as a function of land tenure (spontaneous and planned settlements, ranching, logging and extractive reserves) and soil nutrient status. We will evaluate the patterns of land-cover change, incorporating socio-economic and policy modifications, such as the new zoning programs and reduction in legal area for deforestation that may drastically alter future scenarios of land-use in the region. The knowledge generated will be incorporated into the Zoning Program for the State of Acre and the Ecosystem Management and Global Change Programs of the Federal University of Acre.

This proposal seeks to address the following questions, derived from the LBA-Ecology research announcement:

1. Given that estimates of state-level deforestation rates differ in some cases by a factor of two, how may we improve the accuracy of remote sensing estimates of deforestation and land-use at the local and regional scales such that the data are more useful both for modeling carbon fluxes and for land-use management?
2. The official data on logging and burning are frequently misleading. How can more dependable estimates of these activities be made? How can we differentiate the burning of felled forests, pastures and undergrowth in logged and primary forests?
3. Lateral migration of forest types with differing biomass, as well as in situ changes in mortality and growth, affect carbon fluxes between the atmosphere and the biosphere. How important are such migration and in situ changes for the carbon budget in western Amazonia?
4. How may the knowledge generated by this and other NASA research reach local and regional societies so as to promote the prospect of sustainable land-use?

The following hypotheses form the core of the study effort:

- Hypothesis 1. Scale and classification factors seriously affect deforestation estimates.
- Hypothesis 2. Small-scale deforestation and burning are poorly measured on annual basis.
- Hypothesis 3. Hot pixels of NOAA/AVHRR imagery indicate fire frequency on a daily basis and distribution in western Amazonia.
- Hypothesis 4. Coupling deforestation rates with forest types will substantially improve estimates of carbon fluxes in western Amazonia.
- Hypothesis 5. The life cycles of bamboo-dominated forests affect the carbon budget of western Amazonia on a decade time-scale .
- Hypothesis 6. Carbon cycling of large trees in primary forests is spatially and temporally discontinuous. Forest C uptake is nearly uniform spatially and continuous in time, while release is discrete in time and space.
- Hypothesis 7. Annual Landsat TM imagery improves estimates of logging activities in western Amazonia.
- Hypothesis 8. Re-growing forests represent a minor sink of carbon in western Amazonia.
- Hypothesis 9. Agroforestry systems in converted lands increase vegetative biomass and decrease fire frequency as compared to neighboring converted lands without agroforestry systems.

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Land Cover Conversion in Amazonia, the Role of Environment and Substrate Composition in Modifying Soil Nutrient Cycling and Forest Regeneration.

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Summary

We will integrate remote sensing, GIS and field sampling of soil and vegetation to develop predictive models relating land cover change to its effect on nutrient cycling along the environmental gradients proposed as LBA transects. We predict that differences in substrate composition and environment will drive distinctly different rates of regeneration and affect the duration of pasture use, thus requiring different approaches for sustainable management. We will conduct time-series analysis of land-cover change using Landsat MSS and TM combined with radar to enhance discrimination of pasture and early stages of forest regeneration. Our initial focus will be in Rondônia and Marabá, where historical satellite data have been assembled and analyzed, and where a large body of process level soils and vegetation data already exist. Site selection for soil biogeochemical sampling will be driven by explicit, rule-driven mapping of terrain attributes (initially from digitized topographic maps) and land-cover/land-use maps derived from remote sensing. Soils and vegetation will be sampled for laboratory analysis of cations, exchange properties, carbon, nitrogen, bulk density, wet chemical extraction of P from different pools, and possibly $^{87}Sr/^{86}Sr$ isotopic ratios for nutrient provenance. We will develop mechanistic models that relate soil nutrient composition and dynamics to soil. At each sampling locality the effect of land cover conversion and subsequent management will be documented by analysis of N, P , mineral composition and cation pools existing in soils on comparable landforms. Analyzed along the transects, these data will allow development of a mass balance understanding of weathering, mineral transformation and the nutrient supplying status of Amazon basin ecosystems as affected by environment and substrate.

Our long-term objective is to develop empirical/predictive biogeochemical models with a focus on nutrient dynamics linked to environmental gradients and land cover change. We will predict and test our models using current/future remotely sensed data sets. These models and observations will be critical to understanding ecosystem dynamics as influenced by land-use decisions and should contribute to sustainable management practices in the region. Our research will contribute directly to the larger LBA objectives and will be informed by results from other team members.

General Strategy

We will be operating over a cascading hierarchy of scales. The broadest scale being the Amazon basin which will be segmented by the LBA transect structure. The next scale will focus on the region around the intensively studied tower sites, which we expect will be underlain by a specific geologic formation. Within the intensive study sites we will conduct further stratification by two methods. First, we will use digital topography data to calculate terrain attributes that will allow us to segment the study sites into landforms and landform elements that are grouped according to similar statistical and physiographic properties. At the most detailed level of separation (in this case, determined by data resolution), we will develop variograms to determine the spacing required for collection of uncorrelated samples. We will then be able to collect random samples at that level. This explicit, statistically based sampling scheme allow upward scaling of results based on topography which is extremely important but we will have to overcome data limitation problems through digitization of paper maps until topographic data are generated by airborne campaigns or satellite. Second, we will develop land cover maps and land use history maps using remote sensing data. Our remote sensing strategy is to build on our preexisting experience mapping land-cover and land-cover change in Manaus and Marabá to extend these capabilities to Rondônia and other regions along the transect. We have already assembled all of the necessary optical data for Rondônia and some SIR-C data. We will pursue additional radar data, such as JERS-1 data sets being assembled by the Jet Propulsion Laboratory for much of the basin. We have already developed the programs and obtained the computer facilities that will enable us to generate land-cover and land-use histories rapidly in any region of the basin where data are available. Once the topographic hierarchy and land cover/land use history maps are completed, we can compare the two to determine the landscape pattern of land conversion and to ensure that the sampling scheme adequately covers all land cover types.

We will focus detailed sampling on comparisons among primary forest and various land cover classes. As other researchers have done, we expect to make intensive use of pasture chronosequences, which will give us a time history of biogeochemical change. Finally, we will compare biogeochemical behavior in and between different land cover types across the LBA transects. We anticipate that as LBA our soil biogeochemistry data will be useful to plant ecologists and other biogeochemists on the LBA Science Team and expect to adjust sampling priorities to meet the overall needs of the LBA Team.

Remote Sensing Strategy

The remotely sensed methodologies we will employ build heavily off of seven years of prior experience working in several areas within the Amazon basin. We will employ spectral mixture models using reference end-members as described by Adams et al., (1993, 1995) and Roberts et al., 1997a. Through past research in the area we have already developed a spectral library that is applicable to much of the basin. Where new leaf level and canopy level spectra become available they will be incorporated into our existing libraries.

We will use a binary decision tree approach to classify spectral mixture models from Landsat TM and MSS into at least seven classes, including primary forest, second growth, pasture, water, construction (roads/urban), recently burned, and cloud/smoke obscured. We will employ multi-temporal techniques described by Roberts et al, (1997a) to subdivide pasture and second growth forest into age classes to establish rates of pasture maintenance and regeneration. Potential for regeneration and sustainable land use will vary as some function of intensity of pasture use and age. Images will be screened for clouds using techniques described by Roberts et al. (1997a). Classification errors can be reduced through use of time series as well. Difficulties will occur in separating green pastures and some types of agriculture from second growth forest. This problem is expected to be particularly significant in Rondônia, which has extensive pastures, croplands and some plantations. To facilitate mapping we will explore use of L band radar, using SIR-C data where available (such as Rondônia) and JERS-1 in other regions.

If new remotely sensed optical and microwave data sets become available during the course of LBA we will take advantage of them opportunistically. For example, we have extensive experience in the analysis of AVIRIS data for mapping vegetation. We have already obtained and analyzed some AVIRIS data collected in the state of Rondônia during the SCAR-B program. If enhanced TM or LEWIS HSI data become available we will use them as part of our strategy for testing predictions for regeneration success and explore their capabilities for improvements in spectral libraries and vegetation classification.

Landscape Modeling, Site Selection, and Scaling of Results

A suite of Earth processes combine with land use to act as driving variables that determine the present state of soil biogeochemistry in Amazon ecosystems. The importance of individual controls is scale dependent. At the physiographic region level, gradients in climate coupled with underlying geology drive the properties and processes of soils and ecosystems. Rainfall may be seasonally limiting in parts of Amazonia; at the same time nutrients may be conserved relative to the wetter regions. The nature of soil parent material and the depth to fresh rock (containing nutrients) are significant determinants of biogeochemical functioning. More locally where climate and geology are relatively uniform, topographic variation controls soil biogeochemical functioning because of redistribution of water and soluble nutrients along flow paths. Topography modifies Human land use in predictable ways (i.e. certain landforms will be utilized more than others). In this proposal we will quantify variations in soil biogeochemistry as affected by natural and anthropogenic processes acting at these different scales.

The spatial distribution of soil properties (soil-landscape) is part of the overall ecosystem and is a primary control on nutrient dynamics. A soil-landscape is a complex geomorphologic, biogeochemical and hydrological system that controls the composition and productivity of ecosystems and their response to disturbance. The characteristics of the soil-landscape provide essential information for modeling the pools, pathways and fluxes of water and nutrients. The key components for determining soil biogeochemical properties are quantitative spatial models that include, but are not limited to soil properties such as A-horizon depth, overall soil depth, clay content, cation exchange capacity, organic matter content, available nutrients, nutrient supplying capacity and bulk density. Topographic variation within the soil-landscape system modifies ecosystem functioning by changing fluxes of water, energy and mass. Long-term differences in fluxes can be inferred from differences in measured soil properties. The spatial distribution of soil properties drive the location of monitoring sites for short-term ecosystem-specific fluxes within the soil-landscape system such as water balance and nutrient availability.

Although it is difficult to measure below ground soil-landscape characteristics, we can develop statistical relationships between soil properties and terrain attributes such as slope, aspect, hill-slope position, and slope shape. Our approach, developed by Paul Gessler and others (Gessler et al. 1995, McSweeney et al., 1994, Moore et al., 1993), integrates a geographic information system (GIS), digital terrain modeling, and statistical modeling to quantify relationships between soil properties and terrain attributes, which are calculated from continuous digital elevation models using GIS map algebra tools. Terrain attributes are inexpensive to map over large areas and quantitatively describe the distribution of landscape processes (e.g. water flow convergence/divergence, sediment and solute transport, solar radiation). The distributions of terrain attributes can be used to design sampling schemes that capture the full range of landscape variation and to predict soil biogeochemical characteristics. By then sampling across the range of terrain attributes, we build statistical models relating landscape structure to soil biogeochemical properties. These models allow explicit aggregation of point measurement data or simulation model output (based on point source input data) to landscape scales.

Implementation procedures in Amazonia are as follows:

5. Work in conjunction with the science team to identify priority physiographic provinces to cover a range of climate and substrate. We expect to start in Rondônia as part of the mesoscale catchment study and the first tower cluster along western transect
6. Develop digital elevation models from various sources: digitized 1:100,000 scale maps being competed by Tom Dunne's research team (we expect to digitize maps as well), new topographic mapping technology such as TOPSAR, Global Topographic Mapping Mission and laser altimetry, and semi-quantitative measures of topographic attributes using remote sensing data
7. Calculate (Moore et al., 1993) and map (Gessler et al., 1995) terrain attributes that are appropriate to particular landscapes (we expect to be hampered the lack of data at appropriate scales)
8. Use variogram analysis to determine minimum distances between sample sites required for random sampling of soil and biogeochemical properties
9. Overlay land use and land cover classes on the terrain attributes to determine preferential locations of land cover change
10. Modify topographically driven soil biogeochemistry sampling plan to ensure that all land cover types are represented.

Soil Biogeochemical Sampling and Analysis

At each site we will characterize the weathering and nutrient status of soils by sampling 3 detailed profiles further augmented by randomly distributed core samples to document soil variability. Core sample site selection will be driven by the statistical analysis of digital elevation models described above. Soil profiles will be described according to USDA specifications (Soil Survey Staff, 1992). Channel samples of each horizon will be taken for analysis of total elements, mineral composition, bulk density, pH, exchange capacity, exchangeable cations, cations in soil solution, phosphorous, carbon, and nitrogen.

Weathering and elemental losses from soils will be studied. Soil weathering leads to significant leaching losses of the soil-derived nutrient elements (K, Ca, Mg, P), Si, and even Al. It is critical to document the weathering state of the different substrates because it is indicative of the nutrient reserve for the ecosystem. The amount of elemental loss relative to the parent material provides a measure of the weathering state of a soil profile and its present nutrient supplying capacity. Recent development of physio-chemical strain gauge based on mass balance allows the use of accumulated strain to calculate chemical gains and losses (Chadwick et al., 1990). An immobile element, i, (e.g. Zr) is used to compute the change in volume during pedogenesis as follows:

$$i,w = (pCi,p/wCi,w) - 1 \qquad (1)$$

Where is dry bulk density (g cm^{-3}), C is element mass (wt. %), w is weathered horizon, and p is parent material. Negative values represent collapse of the profile. Once the bulk strain is computed, chemical mass gains and losses of a mobile element, j, per unit volume of parent material, j,w (g cm^{-3}) are calculated with eq. 2:

$$j,w = (wCj,w(i,w + 1) - pCj,p)/100. \qquad (2)$$

Elemental analyses will be made by inductively coupled plasma spectrometry on fused or acid (H_2SO_4, HNO_3, & HF) dissolved soil material for all major rock forming elements.

Nutrient and mineralogical distribution within soils. In addition to the total mass of elements, selective wet chemical extractions are used to document the form that an element is in: exchangeable, organically bound, bound in secondary minerals, bound in primary minerals. Exchange bases are determined using NH_4OAC extraction, exchange Al by KCl extraction and exchange capacity by the sum of bases and Al (Soil Survey Staff, 1992). Soil organic C and N will be determined using a Carlo Erba CNS analyzer; Standard procedures will be used for bulk density and pH (Soil Survey Staff, 1992).

The quantity, chemical forms, and availability of soil phosphorus are particularly important. The dominant forms of phosphorus vary systematically with soil mineralogical and chemical properties (Walker and Syers, 1976; Cole and Heil, 1981; Schimel et al., 1985; Smeck, 1985, Cross and Schlesinger, 1995). That variation often regulates carbon and nitrogen dynamics in the long term. We propose to evaluate the forms of soil P using Tiessen and Mohr's (1993) modification of the Hedley et al. (1982) sequential extraction procedure. This procedure yields P fractions that are operationally defined, but experience has shown that they correlate quite well with Walker and Syers (1976) conceptually defined pools of P (Crews et al., 1995).

Mineral composition which controls cation exchange capacity and P sorption properties will be determined using X-Ray Diffraction, and for selected samples, a series of sequential extractions (Chadwick et al., 1990; Chadwick et al., 1994). For each of these samples, gravimetric weight loss is measured after each treatment. Selective dissolution procedures are as follows:

1. removal of organo-metal complex with peroxide (Wada, 1989)
2. removal of non-crystalline allophane, imogolite, and ferrihydrite using acid ammonium oxalate in the dark (McKeague and Day, 1966)
3. removal of crystalline goethite and hematite by Na-dithionite and Na-citrate using the Blakemore and others (1987) modification of Holmgren (1967) procedure
4. removal of the poorly crystalline aluminosilicates and gibbsite using (Jackson and others, 1986)
5. removal of kaolin by heating the residue to 500 °C followed by a 0.5 M NaOH extraction.

Quantification of nutrient provenance is important to understand biogeochemical dynamics. Strontium isotopes can be used to determine the provenance of calcium and quantify the relative amounts contributed by silicate weathering and atmospheric dust and rain (Capo et al., in press; Stewart et al., in press; Graustein, 1989). In order to interpret $^{87}Sr/^{86}Sr$ values, clear differences must exist between the $^{87}Sr/^{86}Sr$ values of soil parent material and atmospheric input. At this time we do not know if we can apply the technique uniformly across Amazonia. As part of this project we will collect preliminary samples for analysis and if warranted we will propose a parallel study designed to identify the nature of nutrient recharge to the Amazon ecosystems.

Plant and Litter Nutrients. The nutrient status of plants and the distribution of species in a landscape provide a natural measure of the nutrient supplying capability of the soil where they are growing. The youngest fully-expanded stem of mature, sun leaves will be analyzed for leaf mass per area, N, P, base cations, Fe and Al. We will measure N mineralization using intact core incubations and N and P availability using resin bags. We anticipate that leaves taken from trees growing on from nutrient rich soils will have enhanced P concentrations compared with leaves from nutrient poor soils. This approach is not without problems - element storage within vegetation and dilution of element concentrations by growth as well as soil nutrient availability affect foliar concentrations (Chapin et al., 1990).

The selection of measurements is based on data required to develop mechanistic models of soil biogeochemical processes. We have over 20 years of experience interpreting the processes that lead to measured properties. Although developing mechanistic models is our major focus, a subset of these data can also be used as input to ecosystem simulation models such as CENTURY (Parton et al., 1988). We can run CENTURY simulations to compare with our mechanistic understanding and contribute the edaphic input parameters to other members of the LBA Science Team.

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Meteorology and C & N Transport for LBA-Ecology

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Hypotheses and Cautions

We assert several points about the atmospheric environment of LBA-Ecology, which appear reasonable. Only newly funded work under LBA-Ecology will allow us to test these and to aid the ecological community with their interpretation of atmospheric concentrations of CO_2, CO, CH_4, N_20, and aerosols, as well as assessments of carbon loss from Amazônia.

11. The atmospheric environment of the LBAE study area will be affected by inflow of outside air in the lower troposphere, and the inflow will be greatest during the rainiest seasons. These will at least dilute the concentrations of trace species like nitrous oxide, methane, isoprene carbon monoxide natural particulate matter, etc. The rainy season period will also be the period of the most dramatic vertical stirring, e.g., by cloud downdrafts, with similar effects. See also the MTPE proposal, attached, especially the front page, showing strong effects even during the dry season.
12. Composition of the inflow air is complex. For example, in March and April, there is inflow of air from clean ocean regions to portions of Amazônia. However, significant inflow from northernmost South America and the Caribbean, and also more southern regions of South America occurs. All these regions have burning or industrial pollution during these times. The largest potential inflow of complex, polluted, air is, however, from nearby subSaharan Africa, which is at the height of its burning season. As the preliminary work of the citation indicates, these effects may be sporadic and poorly quantified at this point, but are not to be neglected.
13. The loss of isoprene and other organics from the Amazônian system provides a gross loss of C from the system, 1.5% to 4% of NPP. Such percentage affects the perception of an agrading ecosystem when periods of 25 to 100 years are considered. CO may constitute 15% to 60% of the "final" products of isoprene oxidation; here, final means that the material can escape the Amazônian region. Other species may rapidly stick to surfaces or be rained out, possibly somewhat downwind. Measurements of CO and organic trace gases in CLAIRE and organic aerosols and condensibles by Paulo Artaxo at various times will inform our estimates of C loss from Amazônia.

Abstract of Proposed Work

We propose to:

6. Compare and improve simulations of the chemical composition of the troposphere over Amazônia as made by American and Brazilian scientists using meteorological mesoscale and larger scale models. USP and Ames scientist have selected past periods of intensive measurement for intercomparison (e.g.. SCARB and ABLE periods). One focus of this work is to compare quantitatively the effects of parameterizations of planetary boundary layer and cloud venting.
7. Allow inferences of the perturbation of the Amazônia lowermost troposphere by outside influences. We will use incisive tracer simulations to highlight expected perturbations on methane, nitrous oxide. Since effects on these long-lived species will be small, and small concentration differences due to transport may nevertheless be used to infer large effects, we will also simulate carbon monoxide, smoke aerosol mass, and perhaps NO / $N0_2$. In addition to the climatic interest in these species, they highlight exchange processes in great detail, and some of these species may be remotely sensed.
8. As measurements accumulate during the LBA period, we expect we can start studies describing the role of isoprene, other non-methane arboreal emissions, and their products on the carbon balance of Amazônia.

These studies serve two purposes: they help define the CO export from that rainforest region to the world during seasons of low worldwide burning, and they affect the Amazônian C and N budgets at a significant level. This level of funding does not allow chemical mechanistic studies of isoprene's return to the ecosystem, but it does allow:

1. Initial studies of the isoprene profiles and concentrations using planetary boundary layer 1d models and thus some information on the isoprene flux from a forest and the location of the "stickiest" gases and aerosols relative to forest surfaces.
2. Large-scale studies of carbon flux from the Amazon based on estimated conversion efficiencies to CO, generically "sticky" organics, or aerosols.
3. Comparisons of observations and measurements will occupy later years of the proposal. Any students involved will need to familiarize themselves with the modeling and chemistry from an early stage of the LBAE program cycle.

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ND-02 Group Augmented Abstract

Biogeochemical Cycles in Degraded Lands: Technical Plan

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Objectives

The objectives of the proposed research are to define and describe the types of landscapes that fall under the broad category of "degraded lands," and to study biogeochemical cycles across a range of degradation found in secondary forests and cattle pastures of Amazonia. Half of the 10-20 million hectares of Amazonian forest converted to cattle pasture are thought to be "in an advanced state of degradation," but "degraded" means different things to different people. Degrees of degradation are poorly defined and quantified, and yet are important with respect to future land-use options and current rates of C sequestration, trace gas emissions, and water use. We define degraded land as that which has lost part of its capacity to support plant productivity, either in the context of agro-ecosystems or as communities of native vegetation. We propose a suite of biogeochemical measurements that may be used as indices of degradation. Organized according to the LBA themes, these include:

CARBON STORAGE AND EXCHANGE: We propose to measure productivity (as rates of above ground biomass accumulation), soil respiration, radiocarbon content of soil CO_2 and of soil organic matter (in collaboration with Susan Trumbore) in a range of degraded lands. We will also measure associated diversity of species of plants and soil fauna.

NUTRIENT DYNAMICS: We will measure net N mineralization, net nitrification, stocks of N, P, and cations in soils and vegetation, fluxes of nutrients in precipitation, throughfall, soil solutions, and stream-water, and activity of soil fauna. We also have proposed a fertilizer experiment in capoeiras to test whether nutrients limit rates of growth of secondary vegetation.

TRACE GAS FLUXES: In addition to CO_2, we will measure emissions of N_2O, NO, and CH_4.

LAND USE/LAND COVER: We also proposed transects of videography using low flying aircraft to improve classification of subclasses of degraded lands and to estimate their relative aerial importance within Landsat TM scenes. Spectral properties of high resolution images will be used to estimate the percentages of vegetation cover and visible bare soils, vegetation index, brightness, greenness, and wetness/shadow components of the land cover. These estimates will be compared to our field data to determine if indices of degradation deduced from image analyses agree with field measurements of biogeochemical processes.

Because the complexity of interactions among land-use histories, soils, and climate makes extrapolation from a few secondary forest tower sites precarious, our proposed studies at numerous secondary forest sites are necessary to capture the range of rates of biogeochemical cycling processes found within the broad class of degraded lands. Our results will be relevant to biogeochemical constraints of sustainable local land management and will be necessary for regional scale models and budgets of carbon and trace gases.

Research Team Responsibilities

- Eric A. Davidson: nutrient cycling and trace gases
- Thomas Stone: remote sensing
- Tatiana Sá: secondary forest chronosequences
- Moacyr B. Dias-Filho: fertilization experiment
- Regina Moller: soil and water analyses
- Claudio R. De Carvalho: fertilization experiment
- Paulo Moutinho: soil fauna, nutrient cycling
- Ima G. Vieira: biomass and species diversity in secondary forests
- Daniel Markewitz, (WHRC/ University of Georgia): nutrient stocks and fluxes in soils and vegetation
- Paul Lefebvre, (WHRC): research assistant, remote sensing
- Elizabeth Belk, (WHRC): research assistant, trace gas fluxes

Study Sites

Study sites that were proposed include:

14. the primary tower site cluster (e.g., primary, secondary, and logged forest and cattle pasture) of the LBA eastern Amazon transect (in collaboration with Keller's group and others)
15. a broad survey of degraded lands in the vicinity of this tower site, and areas of ongoing studies in eastern Pará state, where chronosequences of secondary forest sites have been identified in Peixe Boi, Igarapé Açu, and Paragominas
16. comparisons of eutrophic and dystrophic soils in Acre (in collaboration with Foster Brown's group)

Activities

- Site selection, biomass studies and surveys of species diversity: 1998-1999
- Nutrient stock measurements: 1998-1999
- Trace gas measurements: 1998-2000
- Fertilization experiment: 1999
- Videography: 1999 and/or 2000

Last Updated: May 18, 1998

ND-03 Group Augmented Abstract

Linking Soil Biogeochemistry to Surface Water Chemistry in Small Drainage Basins of the Amazon

Linda A. Deegan -- Marine Biological Laboratory (MBL)
Reynaldo Victoria -- Centro de Energia Nuclear na Agricultura (CENA)
Christopher Neill -- MBL

Objectives

We propose studies on the effects of conversion from rainforest to pasture on the biogeochemistry of small streams in the Amazon basin. Questions about how organic matter and nutrients move from uplands to streams, how land use alters those inputs and controls, and how terrestrially-controlled inputs are reflected in successively larger streams, are central to our understanding of the ecological functioning and material fluxes in drainage basin networks Our research will focus on three questions about how the dominant land use conversion now occurring in the Amazon Basin-the conversion of moist tropical forest to cattle pasture-changes the biogeochemistry and ecological functioning of small streams in the Amazon Basin:

- **Question 1:** What is the role of uniform forest and pastureland use in the drainage basin in determining the biogeochemical composition of stream waters?
- **Question 2:** What is the effect on stream organic carbon production of altered nutrient inputs from the drainage basin?
- **Question 3:** Are patterns of nutrient concentrations, organic matter and control of organic matter production associated with forest or pasture land use identifiable and persistent in successively larger drainage basins?

We will measure stream chemistry in paired drainage basins with second order streams and uniform land-use and in larger streams and rivers of mixed land-use. One drainage basin in each pair will have land use exclusively of native forest, the other exclusively of cattle pasture. Stream water measurements in paired basins will be made bi-weekly as a minimum during two month-long field trips, one during the period of low flow and one during the period of high flow. When possible, these periods will be supplemented with collections during the wet-dry and dry-wet transitions. To characterize stream biogeochemistry, we will measure pH, conductivity, NO_3-, NH_4+, PO_4^{3}- (as soluble reactive phosphate), dissolved organic N and P (DON, DOP), K+, Na+, Ca_2+, Mg_2+, Al_3+, Fe_2+, Si, Sr, Cl- and SO_4^{2}-, total suspended solids, suspended chlorophyll a, and the C, N and P content of suspended solids. We will add to these measurements the concentrations of total DOC and in different size fractions determined by ultrafiltration. We will also measure the (^{13}C value of the POC and the DOC in the different fractions. To provide more detailed information on stream discharges and element concentrations over a range of discharges, we will install recording stage and temperature/conductivity sensors and autosamplers. To test whether P limits algal growth in the forest streams if light limitation in removed, we are deploying nutrient bioassays. We will measure the concentrations of inorganic nutrients, other anions and cations, DOC and the (13C value of DOC in a series of slightly larger streams.

Contribution to LBA-Ecology

This research program will contribute LBA Ecology an understanding of the ways in which changes in land affect stream biogeochemistry and influence downstream transport of materials. The work in small basins will develop a detailed picture of the characteristic concentrations of nutrients, other ions, DOC and (13C of DOC and POC derived from uniform land-use forest and pasture watersheds. The work in larger streams, including streams formed by the confluence of the small streams in our uniform land use basins, will allow us to trace the persistence of patterns present in the uniform-use watersheds in successively larger drainage. We will also conduct bioassay experiments of N and P limitation in these larger streams draining mixed land use. These experiments will tell us how changing nutrient concentrations and nutrient ratios influence stream organic matter production and how much land use change in a mixed land-use basin must take place before patterns of stream primary production are altered. This project will integrate an understanding of upland- small stream linkages into a landscape and drainage-basin network perspective that takes into account the extent of forest conversion in different-sized basins and how the biogeochemical changes resulting from that forest conversion are transmitted downstream to the larger rivers of the Basin.

Research Team Responsibilities

- Linda Deegan: Algal bioassays & stream nutrient chemistry
- Christopher Neill: Stream nutrient chemistry, soil chemistry and data-loggers for physical parameters.
- Reynaldo Victoria: Concentration, size fractionation and ^{d13}C value of DOC.

Research Sites

We would like to continue our work at Fazenda Nova Vida and extend this work to the LBA paired drainage basins. We have over 3 years of work on two paired drainage basins on Fazenda Nova Vida, a 20,000-ha cattle ranch in central Rondônia. These basins contain permanently flowing second-order streams and are matched closely in area and discharge. The forested basins contain moist terra firme forest typical of Rondônia. They have soils (Kandiudults and Paleudults) that are typical of large areas of the western Amazon Basin. First and second order forest streams in the region are typically 1 to 4 m wide, with clear water and sandy bottoms, and a pH of 5.5 to 6.8. Forest vegetation consists of open perennially evergreen broadleaf trees with a high number of palms. Pastures have been planted to grasses that are widespread in Amazonia, including colonião (Panicum maximum) and several species of the genus Brachiaria. Soils are well-drained ultisols (red-yellow podzolic latosols in the Brazilian classification). Clay content ranges from 10 to 40%. Forest soil pH is ~5. We will also pursue the possibility of making many of the same kinds of measurements in another pair of small basins of uniform land use that will be outfitted for intensive hydrological studies (Martin Hodnett, Institute of Hydrology, Wallingford, UK, personal communication).

Activities

- We are assuming we can begin activities in mid-1998.
- Stream chemistry and bioassays in paired basins - biweekly during one-month periods in the wet and dry seasons - June 1998 - Dec. 2000.
- Stream bioassays for primary production nutrient limitation - June 1998 - Dec. 2000.
- Stream chemistry in larger, mixed land-use streams - June 1998 - Dec. 2000.
- DOC characterization in paired drainage basins and larger streams - June 1998 - Dec. 2000.

Last Updated: May 18, 1998

CD-01 Group Augmented Abstract

Spatial Integration of Regional Carbon Balance in Amazônia

Scott Denning -- University of California-Santa Barbara
Pedro L. Silva Dias -- Universidade de São Paulo
Raymond L. Desjardins -- Agriculture Canada
Maria Assunçao Silva Dias -- Universidade de São Paulo
Humberto Ribeira da Rocha -- Universidade de São Paulo

Objectives

We propose a three-year research program to estimate the basin-scale carbon balance of Amazônia, using a combination of data collected by flux towers, light rental aircraft, and remote sensing, and geographic information systems, interpreted and integrated with numerical modeling of ecosystem carbon flux and regional atmospheric. Tower flux data from sites in intact forest, re-growing forest, pasture, and savanna, will be used to calibrate a model of ecosystem physiology and biogeochemistry (based on the component models SiB2 and CASA) for each major cover type in the region. This model will be coupled to a mesoscale atmospheric model (RAMS), to investigate the propagation of the "signal" of terrestrial carbon flux into the local and regional atmosphere. Light aircraft will be used to estimate regional convective boundary-layer budgets of CO_2 and its stable isotopes, and these data will be used in conjunction with the model to estimate carbon budgets of each cover type over much larger areas than is possible from the towers. The improved ecosystem model will then be applied across the basin using remotely sensed data and a GIS, to calculate the spatial structure of ecosystem carbon flux throughout the year. These estimated fluxes will be used in the mesoscale atmospheric model to predict 4-dimensional fields of CO_2 and $d^{13}C$, which can be compared to data collected by later aircraft campaigns such as LBA-CLAIRE or TRACE-B, when they become available. It is hoped that our results will allow reliable carbon budget estimation in other regions from EOS data in the future using relatively inexpensive aircraft sampling programs.

Research Team Responsibilities

- Scott Denning: Model development and integration
- Pier-Luigi Vidale: SiB2-RAMS programming
- Lara Prihodko: Remote sensing, GIS, model parameterization
- Raymond L. Desjardins: Aircraft instrumentation, CBL budgets
- Pedro L. Silva Dias: RAMS 4-D data assimilation
- Maria Assunçao Silva Dias: RAMS 4-D data assimilation
- Humberto Ribeira da Rocha: SiB2 site calibration
- Joe Berry: SiB2 site calibration

Preferred Sites

We will necessarily work with whatever sites are chosen for eddy covariance flux towers. We prefer to work with flux tower sites in (1) intact forest; (2) re-growing forest, (3) savanna, and (4) pasture. The CBL budget work is designed to work with a "lake-breeze" circulation in the vicinity of a large body of water, and would add significant value to the flask air sampling program proposed by Tans, Bakwin, and Artaxo, if it were located between their sampling sites (Belém and Manaus). We have identified the area around Santarém, Pará as a likely site that meets most of these criteria.

Activities

- **1998:** Develop and test the coupled SiB2-CASA carbon model. Couple this to RAMS.
- **1998-1999:** Perform site calibration of SiB2-CASA model using ABRACOS data, available LBA eddy covariance data, and site meteorology for sites in intact forest, regenerating forest, savanna, and pasture.
- **1999:** Perform LES simulations of PBL structure, CO_2, and $d^{13}C$ at tower flux sites. Perform mesoscale "lake-breeze" simulations of internal boundary layer development and use the results to plan aircraft campaign.
- **1999:** Conduct aircraft campaign (using rental aircraft) to measure CBL budgets of CO_2 and $d^{13}C$ over regional area surrounding one or more flux tower sites.
- **1999-2000:** Obtain basin-scale data products on land cover classification, eco-physiological, and phenology parameters derived from remotely sensed data or provided from other LBA investigators. Use these to parameterize SiB2 across Amazônia.
- **2000:** Perform basin-scale simulations of ecosystem carbon and d13C flux in coupled SiB2-RAMS model, forced with 4-D data assimilation products and nested down to local scale in the vicinity of each LBA flux site. Analyze spatial and temporal patterns, rectifier effect, and produce sensitivity analysis for later aircraft campaigns (e.g., LBA-CLAIRE).

Last Updated: May 18, 1998

LC-03 Group Augmented Abstract

Radar Remote Sensing of Land-Cover and Biomass in the Amazon

Craig Dobson -- University of Michigan
João Soares -- Instituto Nacional de Pesquisas Espaciais-INPE (Brazilian Space Research Institute)
Dalton Valeriano -- INPE
Fawwaz Ulaby -- University of Michigan
Leland Pierce -- University of Michigan
Robyn Burnham -- University of Michigan
Giafranco DiGrandi -- JRC, Ispra
Anthony Freeman -- University of Michigan

Objectives

This proposal supports the scientific goals of LBA in the following technical theme areas: (1) land-cover and land-use change, (2) carbon storage and exchange and (3) trace gas fluxes.

The main cross-cutting themes of the proposed effort are: (1) remote sensing, (2) field observations and (3) GIS development.

Our specific objectives are to use archival orbital imaging radar data (1) to produce land-cover classifications of the Amazon basin, (2) to collaborate in mapping of surface inundation extent/duration, (3) to estimate aboveground biomass and (4) to collaborate in estimation of the biotic carbon pool.

A prototype classifier using orthorectified composites of ERS and JERS SAR data has already been developed and tested on a number of NSF Long-Term Ecological Research Sites and a moist tropical site west of Manaus. Simulations (using SIR-C data) have shown the classifier to be readily adapted to use of the C-band and hh-polarized channel provided by Radarsat. A large number of polygons will need to be inventoried to support classifier development and validation.

Prototype biomass algorithms have also been developed and tested using data acquired by SIR-C, and need refinement and validation for tropical forest types. The orthorectified results will be expressed as digital thematic maps and placed into the LBA GIS.
The issue of spatial scaling will be explicitly treated within a subsample of primary and secondary LBA sites via a nested approach using high spatial resolution data (i.e., SIR-C/X-SAR or airborne SAR if and when available) and lower resolution orbital data (i.e., ERS/JERS/Radarsat at full resolution and also degraded to 100-m resolution). The JERS and Radarsat data were acquired during two sampling periods in 1996. These results will be cascaded into products generated at 100-m resolution for both the main LBA transects (during the first three years) and over the full basin (during the ensuing three years).
The temporal domain will also be explicitly treated. Wet and dry season composites will be used to ascertain (1) inundation extent and (2) land-cover change over a 6-month period (nominally for 1996). In addition, it is expected that the future availability of Light SAR and/or PALSAR data (in the year 2000 to 2002 time frame) may provide the opportunity for evaluation of decadal-scale changes as well.
The remote sensing effort will be supported by field-level activities to help define a network of known land-cover polygons for evaluation of the classification and also conduct biometry of land-cover types (undisturbed forest, regenerating forest, etc.) for validation of biomass/carbon retrieval algorithms. The project includes remote sensing scientists, electrical engineers and biologists with collaborative Brazilian participation.

Research Team

- Craig Dobson: Land-cover classification and biomass algorithms
- Fawwaz Ulaby: SAR scattering and textural attributes
- Leland Pierce: Image processing
- Robyn Burnham: Tropical forest regrowth, biometry, fieldwork
- João Soares: Backscattering mechanisms and implementation of final biogeophysical processor at INPE
- Dalton Valeriano: land-cover inventory and biometry
- Giafracno DiGrandi: ERS SAR
- Students (Hua Xie and another student from Amazon region), University of Michigan

Activities

Land-Cover Classification:

17. Determination of land-cover classes (1998)
18. Define, locate and label training and testing populations of land-cover polygons within primary and secondary sites along the transects (1998)
19. Initial classifications at high resolution (SIR-C/X-SAR and ERS/JERS/Radarsat at full resolution) and at low resolution (100m) (1999)
20. Verification of classifications (1999)
21. Final classification of LBA transects, insertion into LBA/GIS (2000)
22. Derivative products
    - disturbance/change mapping (inundation, clear-cutting, selective logging, conversion)

Biomass:

9. Define, locate and measure biometry for training and testing populations of various land-cover classes (stratified sampling). Use archival data where available. (1998)
10. Initial biomass estimation at primary and secondary sites (1999)
11. Verification of aboveground biomass assessments (1999)
12. Apply final algorithms to LBA transects, insert product into LBA/GIS (2000)
13. Creation of derivative products
    - carbon pool assessment

Last Updated: May 18, 1998

CD-02 Group Augmented Abstract

Carbon and Oxygen Isotope Ratio CO_2 Flux Analyses at the Soil, Canopy, and Landscape Scales

James Ehleringer -- University of Utah
Luiz Martinelli -- Centro de Energia Nuclear (CENA), University of São Paulo, Piracicaba, Brazil
Lawrence Flanagan -- University of Lethbridge
Craig Cook -- University of Utah

Objectives

We propose studies in carbon storage and exchange. We propose to work in disturbed and undisturbed sites along a C3/C4 gradient (savanna to rainforest).

Project Overview

We propose to measure stable isotope ratio measurements of atmospheric CO_2 to infer changes in terrestrial ecosystem photosynthesis and respiration (sink or source strength) on local and regional scales. These measurements will be made in conjunction with soil respiration rates and collaborative studies with eddy flux tower studies. Within terrestrial ecosystems, photosynthesis and respiration have different and contrasting effects on the carbon and oxygen isotope ratio of atmospheric CO_2. Monitoring shifts in both the concentration and stable isotope ratio of atmospheric CO_2 can be used as a tool to study large scale terrestrial ecosystem gas exchange processes, but the linkages of ecosystem and regional isotope ratio signals have not been attempted in the past. Regional and global interpretation of the stable isotope signal recorded by the atmosphere requires an understanding of fractionation processes that occur during ecosystem gas exchange processes. While we have gained a mechanistic understanding of leaf-level isotope effects during photosynthesis and respiration, we need to extend and apply our knowledge of isotope effects to the ecosystem- and regional-level in order to constrain models so that calculations of large scale ecosystem gas exchange processes can be made with confidence.

We have developed a nested sampling scheme for measuring isotope effects associated with photosynthesis and respiration at three spatial scales: (i) individual chamber at the soil surface; (ii) canopy tower for canopy and/or ecosystem level; (iii) aircraft sampling of changes in the convective boundary layer for the regional level. Our research plan will allow us to determine the impacts of land-use changes (conversion of C3 forest to C4 pasture grasses) to regional productivity because the C3 and C4 plants have very different isotope effects during photosynthesis. Interannual variability associated with El Niño/ La Niña events should also have substantial effects on the timing and magnitude of ecosystem gas exchange processes and associated isotope effects. Direct measurements of the effects of El Niño/ La Niña events on isotope effects during photosynthesis and respiration are needed for future large scale isotope modeling studies.

Proposed Measurements

The proposed study will make several key LBA-Ecology measurements at each of the three primary regions along the east Amazônia transect between Brasília and Manaus, including:

- soil respiration rates
- carbon isotope ratio analyses of soil organic matter
- carbon and oxygen isotope ratio analyses of leaf material
- carbon and oxygen isotope ratios of CO_2 within the soil
- carbon and oxygen isotope ratios of CO_2 released from the soil surface
- carbon and oxygen isotope ratios of total ecosystem respiration
- carbon and oxygen isotope ratios of ecosystem photosynthetic discrimination
- carbon and oxygen isotope ratios of landscape-level respiration
- carbon and oxygen isotope ratios of landscape-level photosynthetic discrimination
- carbon and oxygen isotope ratios and profiles of CO_2 within the convective boundary layer

The measurements are proposed to be collected 2-4 times per year, depending on parameter complexity and other team-project considerations. Our studies will be conducted in close association with simultaneous eddy covariance measurements, made by other researchers, in order to obtain information about ecosystem photosynthesis, respiration and turbulent exchange. The leaf- level, canopy- level, and regional-level models of isotope fractionation can be used to determine the effect of different terrestrial ecosystems on the carbon and oxygen isotope ratio of atmospheric CO_2, because of differences in photosynthetic pathway, ecosystem composition, and environmental influences. The information gathered using our isotope studies would help in determining the role of the Amazon Basin as a net sink or source of CO_2 to the atmosphere.

Preferred Sites

Our interest is in spanning from seasonally dry cerrado ecosystems (Brasília) to seasonal rain forests (Pará) and through aseasonal rainforest ecosystems (Manaus). Primary research sites in each of three major areas along this geographic transect will be chosen in (a) primary rainforest or cerrado, (b) pastures derived from primary forest conversion, and (c) secondary growth forest. This provides us with 9 different sites with which to examine ecosystem and land-use changes (canopy and soil levels) and with 3 regions across Amazônia with which to examine landscape processes. Strong isotope ratio gradients exist at each of the major sites that should allow us to differentiate carbon turnover and respiration sources. Clear C3/C4 differences in species composition exist between forest and pasture species along this entire gradient. Virtually all of the pasture species (native and introduced) have C4 photosynthesis and all of the forest species have C3 photosynthesis. A potentially strong C3 - C4 gradient exists as well in the transition between tropical rainforest and cerrado ecosystems.

Education

This proposal provides a strong education component, which includes training Brazilian graduate and postgraduate scientists. We plan to provide lecture/laboratory opportunities for Brazilians to participate in the Utah Stable Isotope Ecology course, as well as exploring development of a similar course in Brazil. There is also the opportunity for other LBA investigators to receive stable isotope ratio training at SIRFER.

Last Updated: May 18, 1998

ND-04 Group Augmented Abstract

Carbon and Nutrient Stocks, and Soil Water Dynamics in Abandoned Pastures and Agroforestry Systems in the Central Amazon.

Erick Fernandes -- Cornell University
Rogerio Perin -- Empresa Brasileira de Pesquisa Agropecuaria, Centro de Pesquisa Agroflorestal da Amazonia (EMBRAPA-CPAA), Manaus
Neliton Silva -- Federal University of Amazonas, Manaus (FUA)
John Duxbury -- Cornell University
Susan Riha -- Cornell University
Ilse Ackerman -- Cornell University
Karen McCaffrey -- Cornell University
Steve Welch -- Cornell University
Elisa Wandelli -- EMBRAPA-CPAA
Silas Garcia -- EMBRAPA-CPAA

Objectives

We propose studies in three theme areas of LBA: carbon storage; nutrient dynamics; and trace gas fluxes. Training of Brazilian collaborators and graduate students is an important goal. We propose to evaluate soil biogeochemical processes on degraded pastures and in six-year-old agro-silvopastoral systems at the EMBRAPA-CPAA experiment site located 54 km from Manaus on BR 174 and adjacent to the primary forest site used by INPA. The degraded pastures are on the widely distributed clayey Oxisol (clayey, kaolinitic, isohyperthermic, Xanthic Hapludox).

Carbon Stocks. Our preliminary data from recent work in the Amazon show dramatic increases in biomass accumulation in both native and exotic tree and grass species with modest additions of P and Ca to soils. To assess these priming effects of nutrients, we will measure total system carbon (woody biomass, understory herbaceous biomass, litter fall, surface litter, roots, fine root dynamics and soil) in fertilized and non fertilized pasture chronosequence (2 years to 25 years). Similar measurements will be done in four, well-characterized six-year-old agro-silvopastoral (ASP) systems that were established on degraded pastures. Analyses of C stocks and pools will provide us with data for predictive models of vegetation regrowth and carbon dynamics as a function of management interventions.

Nutrient Dynamics. We will measure nutrient stocks and cycling and water dynamics in both the fertilized and non-fertilized pasture chronosequence and ASP systems. Although the focus of the study will be on P and Ca as major limiting nutrients, the need for nutrient additions will be based on analysis of soil nutrient levels and nutrient availability, coupled with yield projections and nutrient budgets for the systems. We will also measure (a) soil moisture and surface temperature and the resulting soil fauna (decomposer) populations, (b) chemical characteristics (lignin, cellulose, polyphenols, and other nutrients) of the litter, and (c) litter decomposition and nutrient release patterns in the fertilized and non fertilized pasture and ASP systems. We expect to obtain a better understanding of the response of the various components of the decomposers to changes in microclimate, litter quality, and soil nutrient status and thus improve our ability to predict rates of decomposition and hence nutrient release patterns in different pasture and ASP use scenarios.

Our measurements of above and below-ground productivity linked to the physical, chemical and biological factors will provide information on processes controlling carbon and nutrient dynamics in abandoned pastures and the management alternatives to rehabilitate abandoned pasture land. The detailed characterization of the soils, vegetation, management and environmental variables at our site will facilitate extrapolation of the results to other sites.

Research Team Responsibilities

- John Duxbury: Soil carbon and biogeochemistry
- Erick Fernandes: Nutrient cycling, above and below-ground productivity
- Regerio Perin: Managed pastures.
- Neliton Silva: Soil fauna and Insect ecology
- Wilhelmus Sombroek: Soil taxonomy and soil nutrient dynamics.
- Susan Riha: Soil water and nutrient dynamics and modeling
- Elisa Wandelli: Forest ecology and secondary species succession.

Preferred Site

We hope to work in degraded and abandoned pastures in the Manaus region and on agroforestry systems at the EMBRAPA-CPAA experiment station located on the road from Manaus to Boa Vista (BR 174).

Activities

23. Pasture Chronosequence selection - June to August 1998
24. Site & pasture chronosequence characterization- August to December, 1998
25. Site instrumentation and on-site laboratory installation - August to December 1998
26. Above and belowground productivity measurement, pasture chronosequence and ASP systems - Sept. 1998 to Dec. 2000. [Aboveground biomass, litterfall, root cores, soil samples, soil C pools,]
27. Litter decomposition Assays, ASP systems and pasture chronosequence
28. Sept. 98 to Dec. 2000
29. Soil fauna assays, all systems - Dec 98 to Dec. 2000

Last Updated: May 18, 1998

CD-03 Group Augmented Abstract

Periodic, transient, and spatially inhomogeneous influences on C exchange in Amazonia

David R. Fitzjarrald -- Atmospheric Sciences Research Center University at Albany, State University of New York
Osvaldo Moraes -- Universidade Federal de Santa Maria, RS, Brazil
Kathleen E. Moore -- Atmospheric Sciences Research Center University at Albany, State University of New York

Motivation

We propose observations and analyses to infer transports of CO_2, water vapor, and energy from the natural and the disturbed rain forest by making direct and inferential flux measurements. A major focus is to determine how Amazonian carbon exchange is affected by natural and human-induced temporal and spatial variability in the ecosystem.

Objectives

30. To describe the radiation environment of the upper and lower canopy in natural and logged regions, to understand how the intensity and quality of incoming radiation are altered by cloudiness, and to determine what is the resulting effect on net ecosystem exchange of C (NEE).
31. To describe and model the mechanisms of turbulent canopy-atmosphere exchange in regions of closed-canopy primary forest, near natural gaps, and in the cut-over mosaic of a selectively
32. Logged site.
33. To relate canopy layer and boundary layer concentrations of potential temperature, CO_2, and H_2O, and use this information to estimate their partition into surface and canopy source components.
34. To determine what limits the accuracy of long-term tower flux observations of net ecosystem exchange (NEE) in the rain forest.

Work Plan -- Detecting the Importance of Inhomogeneities on Observed Carbon Fluxes

- To describe the ecosystem light environment, we plan to locate radiation booms on the 60 m Rohn towers at the primary forest (PF) and selective logged (SL) sites. These booms are self-contained units that provide long-wave, short-wave, PAR, and net radiation in each vertical direction, and include an electronic level readout. A rotating shadowband radiometer in a clearing will measure diffuse and direct radiation components.
- To make estimates of the respiration rate from tower CO_2 concentration observations, continuous acoustic wind profiler measurements will be maintained. By monitoring the backscatter signal, the thickness of the stable boundary layer will be obtained and the nocturnal surface flux (respiration rate) found by the layer budget approach.
- To determine the importance of natural and artificial gaps on canopy venting, microclimatic studies using turbulence instrumentation and sub-canopy sounding balloons will be deployed at several sites during IFCUs. For selected periods, balloons will also carry small-diameter tubing that will sample the CO_2 profile in the gap, using a battery-operated pump connected to a CO_2 analyzer.
- Sub-canopy flux measurements. The measurements, in conjunction with the profiles of T, q, and [CO_2] proposed by Wofsy and Goulden, offer a unique opportunity to measure and then parameterize the mechanisms of mass exchange between the rain forest and the lower atmosphere.
- Tower representativeness. We will apply and refine existing techniques to determine the source region for surface-based and canopy fluxes, using a vertical profile of turbulence intensity appropriate to the undisturbed and logged forest sites, respectively. We propose to operate a sonic anemometer at levels just above the canopy with the objective to determine at what times this level and tower top may lie in different turbulent microclimates.
- To track cloud fraction and cloud base as 30 s intervals, a ceilometer will be deployed.
- To determine cloud type and to make another estimate of cloud fraction, a digital sky camera will be operated for selected periods. In analysis we will seek to link these cloud characteristics from the surface observations to those from satellite images.
- Two secondary tower sites, to be fitted with automatic weather stations that communicate to the PFsite by radio modem, will provide the minimal surface network for use with mesoscale modeling. This will also

provide the framework to decide if there are systematic biases in climate observations from riverside stations.
- Daytime mixed layer thickness will be found using established relationships between cloud base and mixing layer thickness, using the sounder and ceilometer data in tandem.

Training

We are prepared to give a training course in micrometeorological methods used in ecological studies, to be held in and around Santarém. Since several of the ASRC team are fluent in Portuguese, the material in these courses can be presented in that language or in Spanish. In addition, transfer of the data acquisition system hardware and software to local teams is planned.

Research Team Responsibilities

State University of New York

- David Fitzjarrald: Design and deployment of the boundary layer sounding system for the respiration estimates; planning the flux measurement training program
- Kathleen Moore: Primary responsibility for the field investigation of the forest gap microenvironment studies
- John Sicker: Fabrication of mounting systems for tower-based radiation and turbulence instrumentation; electronic interfaces with other groups, cabling, in the design and maintenance of computer systems
- Ricardo Sakai: Responsible for coordination of field operations in Brazil, assisting in the training program, designing data analysis strategy
- Otavio Acevedo, Jeffrey Freedman, and Ralf Staebler (Ph.D. students): Upgrade to the group's digital sky camera, and the interface between ceilometer and the data acquisition system, and archiving data

Universidade Federal de Santa Maria, RS, Brazil

- Osvaldo Moraes: Analysis of turbulent spectra sub-canopy CO_2 transport models. He will have joint responsibility for field operations and will provide models of turbulent transport within and above the rain forest canopy

Links to Other Groups

Our efforts link to the continuous flux measurements proposed by Wofsy et al. (Harvard University) at the undisturbed Tapajós site and similar observations proposed by Goulden. (University of California, Irvine) at the logged site. The canopy-atmosphere exchange and nocturnal respiration studies link directly to the 222Rn tracer studies proposed by Martens (University of North Carolina) and to chamber measurements planned by Keller, Crill, and Silver and by Goulden. (U.S. Forest Service, University of New Hampshire). Studies of turbulence in the sub-canopy and roughness layers are done in collaboration with O. Moraes (Federal University of Santa Maria, RS, Brazil) . The proposed work links directly with the mesoscale model studies of the river breeze planned by M. Silva Dias (University of São Paulo, Brazil).

Activities

- Installation of automatic weather stations, cloud ceilometer, July-December 1998
- Automatic tower flux measurements; radiation suite on towers, October 1998-2000 (to be reinstalled after logging at disturbed forest)
- IFC gap microclimate measurements, Gap inventory at tower sites, 1-2 months/year 1998-2000

Last Updated: May 18, 1998

The Effects of Tropical Forest Conversion: Ecological Research in the Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA)

Jonathan A. Foley -- Climate, People and Environment Program, University of Wisconsin
Marcos Heil Costa -- Department of Agricultural Engineering, Federal University of Viçosa

Objectives

We have proposed a low-cost effort, focused on LBA-Ecology research agendas, that will build upon our ongoing activities in land surface and ecosystem modeling. Our group is currently funded as an EOS Interdisciplinary Science Team (IDS) by NASA's Mission to Planet Earth.

Our group is currently engaged in an effort to develop an integrated dynamical biosphere model -- the Integrated Biosphere Simulator (IBIS). Our modeling approach reconciles the disparity of the existing land surface packages and terrestrial biosphere models by representing a more complete hierarchy of ecosystem phenomena, including:

35. **land surface physics** (energy, water, and momentum exchange within the soil-vegetation-atmosphere system)
36. **canopy gas exchange** (photosynthesis, respiration, and stomatal behavior)
37. **plant phenology** (seasonal cycles of leaf development, leaf senescence, and plant activity)
38. **whole-plant physiology** (allocation of carbon and nitrogen, plant growth, tissue turnover, and age-dependent changes)
39. **vegetation dynamics** (recruitment, competition for resources, mortality, disturbances, and gap formation)
40. **carbon and nitrogen cycling** (flow of carbon and nitrogen between the atmosphere, vegetation, litter, and soils).

Initial versions of IBIS have been used to investigate global patterns of water balance, carbon cycling, and vegetation cover, as well as the potential impact of increasing CO_2 concentrations on the hydrology of the Amazon basin. We are developing a more sophisticated version of IBIS for simulations of global biogeochemical processes, vegetation dynamics, and terrestrial hydrology as part of our funded NASA EOS Interdisciplinary Science Investigation.

Working with other LBA-Ecology investigators, we hope to use our integrated terrestrial biosphere model to evaluate changes in land surface processes, ecosystem dynamics, and terrestrial carbon storage in response to land use activities in Amazonia.

We anticipate that these efforts will proceed along four areas:

14. **Develop an historical perspective of land cover change in Amazonia.** Using a combination of remote sensing products (i.e., Landsat and AVHRR data), long-term national inventory data, and other ancillary data, one can construct an empirically-based model of land use activity and land cover conversion for the Amazon basin.

    We plan to work with LBA-Ecology investigators in developing land use and land cover change scenarios for the Amazon region. In addition, a graduate student in our group, Navin Ramankutty, is currently building a land-use model for reconstructing global patterns of land use and land cover change during the last 100 years. This work could be extended, at little cost, to focus on the Amazon basin as well.
15. **Use land use scenarios as a driver of the IBIS dynamic biosphere model.** Using our IBIS dynamic biosphere model, and land cover change scenarios, we can examine the dynamic processes occurring within terrestrial ecosystems that give rise to carbon sources and sinks. Using IBIS to simulate dynamic ecosystem processes will provide several advantages over other modeling approaches, because it simulates land surface processes, canopy physiology and gas exchanges, biogeochemical cycling, and vegetation dynamics in a single, physically-consistent modeling framework.

    We plan to collaborate with LBA-Ecology investigators to develop appropriate simulation experiments, and to coordinate data exchange and model intercomparison activities.

16. **Validate model simulations against hierarchical of surface and remotely sensed observations.** Working with data generated by LBA projects, we will be able to compare our simulations of land surface processes and ecosystem dynamics against a full suite of observations. These observations include (we hope) streamflow data, tower flux data, isotope samples (i.e., $^{13}C/^{12}C$, $^{18}O/^{16}O$), and satellite measures (including data from Landsat, AVHRR, and MODIS). Our integrated biosphere modeling approach, unlike other modeling frameworks, will facilitate a more complete validation procedure by linking direct biophysical measures (e.g., canopy spectral reflectance, energy and water fluxes, and isotopic fractionation) and longer-term ecological, biogeochemical and hydrological measures (e.g., leaf area index, biomass, soil carbon, runoff and river discharge).
17. **Evaluate response of net carbon exchange to land use scenarios.** Finally, we will be able to examine how changes in land use (past, present, and future) may affect the gross carbon budget of the Amazonian region.

To facilitate communication and collaboration with Brazilian scientists, we will coordinate our efforts with Prof. Marcos Costa, who is currently working with Foley's group at Wisconsin. Costa is a Professor in the Department of Agricultural Engineering at the Federal University of Viçosa.

Last Updated: May 18, 1998

LC-11 Group Augmented Abstract

JERS1 Amazon Multi-Season Mapping Study (JAMMS)

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John Baker -- British National Space Center
Bruce Chapman -- Jet Propulsion Laboratory
Luciano Vieira Dutra -- The National Institute for Space Research
Rick Guritz -- Alaska SAR Facility
John M. Melack -- University of California
Bruce Walker Nelson -- National Institute for Amazon Research
Ake Rosenqvist -- Joint Research Centre of the E.C.
Sasan S Saatchi -- Jet Propulsion Laboratory
Masanobu Shimada -- National Space Development Agency of Japan

Objectives

Amazon Basin using radar images from the Japanese JERS-1 (Japanese Earth Resources Satellite) Synthetic Aperture Radar (SAR). Because of the radar's ability to see through clouds, a sequence of radar images over this area collected on each overpass of the JERS-1 satellite would result in a unique map of the Amazon Basin in one 44 day repeat cycle.

There is a great deal of interest in the effect of the substantial flooding that occurs along the Amazon. The JERS-1 satellite is particularly well suited to studying the extent of flooding, due to the large amount of electromagnetic penetration to the ground through the forest canopy at this wavelength: the radar waves penetrate to the smooth water surface and "double bounce" off the trees trunks back to the radar, resulting in a bright radar return for these areas.

This project will result in a unique data set, representing not only the extent of inundation of the rainforests, but also mapping man made artifacts such as roads, cities, cropland, and deforestation. This proposed map will be used by the international team of investigators to examine the amount of deforestation present over the entire Amazon Basin. Since radar observations are not hampered by clouds or rain, we will for the first time get a "snapshot" of the current state of deforestation. Comparison of this data set with past and future maps will enable the rate of deforestation to be estimated. In addition, different biological habitats will be distinguishable in the radar images. This data will be made available to scientists studying the Amazon initially through the release of a CD-ROM set containing the data, and later on the Internet.

Radar images from JERS-1 have been used successfully to determine flood extent, basic vegetation type (including clear-cuts), and to study changes in these parameters. We propose to extend our development of algorithms which can be applied to JERS-1 data over the entire Amazon to generate maps of flooding and vegetation type. These maps will be verified against stream gauge date, vegetation maps, field studies, and complementary remotely sensed data from selected sites. These correspond to NASA categories in Land Surface Hydrologic Interfaces, Ecological Processes and Modeling, and Environmental Consequences of Landcover Change and USGCP efforts in Biogeochemical Dynamics, and Ecological Systems and Dynamics.
This project is a collaborative effort with scientists from the Jet Propulsion Laboratory (JPL, U.S.), the University of California –(UCSB, U.S.), the Alaska SAR Facility (ASF, U.S.), The National Institute for Space Research (INPE, Brazil), the National Institute for Amazon Research (INPA, Brazil), the National Space Development Agency of Japan (NASDA, Japan), and the British National Space Center (BNSC, UK).

Last Updated: December 14, 1998

LC-12 Group Augmented Abstract

Using Landsat Data to Develop an Image Based Logistic Regression Model for Predicting Deforestation in the Amazon

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Marcos Pedlowski -- Universidade Estadual do Norte Fluminense
Jessica Steffanski -- University of Cincinnati
Chris Allen -- University of Cincinnati

Objectives

Modeling deforestation has become increasingly important in analyzing the effects of landcover change on ecosystems. The goal of this proposed study is to achieve an improved understanding of those processes which influence deforestation in the tropics. This study will use multi-temporal Landsat data to develop and apply a simulation model for deforestation in colonization areas of the Amazon. The site chosen for this study includes colonization areas of Ji-Parana and Ouro Preto, Rondonia. An integrated socioeconomic model has already been applied to a colonization area in the Amazon Basin of Central Rondônia, Brazil. To accomplish our goal we will:

1. develop a Landsat-based logistic multiple regression model of deforestation for colonization areas of Rondônia, Brazil;
2. apply the Landsat-based model to colonization areas of central Rondônia, Brazil for various time periods.
3. compare the image-based model outputs to those from an integrated socio-economic model and other models of land-use change for the same area and time periods;
4. use multitemporal remote sensing image processing analysis of Landsat satellite data and ancillary data within a geographic information system (GIS) to estimate changes in land-use in Rondônia for the same areas and time periods;
5. and, evaluate and compare the predictive capability of the model using remote sensing analysis and field measurements.

In addition to direct statistical comparisons, a number of spatial pattern metrics will be used to quantify and compare changes in landscape patterns between the model outputs and the remote sensing and ground estimates.

The methodology employed in this research involves:
(1) Database development of Landsat TM and MSS data (Path/Row 231/67 WRS2, and 248/67 WRS1) for 10 time periods 1973-1998.

(2) Model parameterization with variables such as proximity and distance metrics, edge measures, and suitability indices.
(3) Application of the model to colonization areas creating simulation maps of clearing.
(4) Landsat classifications for the same areas and time periods as the model.
(5) Comparison of model outputs to classifications using descriptive statistics, quantitative measures of spatial pattern such as fragmentation and shape complexity metrics, and direct overlay. We have developed a number of spatial indices that have been shown to be independent of spatial resolution for model/classification comparison.
(6) Field verification of model outputs and classifications. Field investigations will be conducted in August and September of 1998 and 1999 in Ji-Parana and Ouro Preto. Digital field maps will be created using a handheld GPS and portable sub-notebook.
(7) Comparison of model accuracy, outputs, and validation with other modeling efforts.

Although, the model is based on Landsat data, the method in developing the model can be easily applied using other remote sensing data. In particular, we plan to employ the use of AM-1 ASTER and MODIS data as well as Landsat-7 data when they are available. We predict that model parameters will be similar for other satellite data. However, we may get more accurate results with the higher spectral and spatial resolution of EOS AM-1 and Landsat ETM+ data.

This research will provide a number of advantages to the LBA-Ecology program.
Results of this study will help determine if there are advantages in the use of integrated socioeconomic/ecological models over traditional methods for modeling land-use change. The understanding developed in the course of this study should facilitate the development of models that better simulate the processes of land clearing, hopefully improving our ability to predict the future impacts of deforestation and land-use change on global and regional ecological processes. Such information will provide LBA-Ecology with the best tools for predicting the impact of colonization and development projects on the forests of the Amazon.

Last Updated: July 13, 1998

LC-05 Group Augmented Abstract

Anthropogenic Landscape Changes and the Dynamics of Amazonian Forest Biomass

Claude Gascon -- Smithsonian Institution
Rita Mesquita -- Instituto Nacional de Pesquisas da Amazônia (INPA)
Jim Tucker -- NASA/Goddard Space Flight Center
Marc Steininger -- NASA/Goddard Space Flight Center
William F. Laurance -- Biological Dynamics of Forest Fragments Project
G. Bruce Williamson -- Louisiana State University
Eduardo Venticinque -- Instituto Nacional de Pesquisas da Amazônia (INPA)
Manoel Pacheco-- Instituto Nacional de Pesquisas da Amazônia (INPA)
Scott Bergen
Gay Bradshaw

Objectives

Our study addresses the LBA Ecology theme of carbon storage and exchange. We propose a combination of field studies and computer modeling to estimate above-ground biomass in continuous forest, forest fragments, and secondary forests of different types through time and to relate these measures to remote sensing data from LANDSAT TM images for a modified landscape in central Amazonia. Our objective is to develop a predictive model of carbon stocks and their dynamics based on readily identifiable landscape features derived from remote sensing imagery.

BIOMASS DYNAMICS IN CONTINUOUS PRIMARY FOREST AND REMNANTS: We will use extensive existing data from a long-term phyto-demographic project in the Amazon, coupled with additional fieldwork, to estimate standing biomass in continuous forest plots and forest fragments. This unique data set includes over 57,000 marked trees in 66 permanent, one- hectare plots. These plots were surveyed initially more than 15 years ago, and have been re-censured 2-5 times to estimate tree growth, mortality, damage, and recruitment, thereby allowing us to monitor the dynamics of Amazonian tree communities and their intrinsic carbon stocks at a landscape level (ca. 1000 km^2). In this project, we will re-survey tree communities in all 66 permanent plots. Lianas will also be included in these surveys because recent results suggest that they could exhibit markedly increased growth rates in response to increasing atmospheric CO_2.
BIOMASS DYNAMICS OF REGENERATING FORESTS: We will develop biomass estimates for different ages and types of secondary forest, in order to assess the rate of carbon accumulation in fallow and regenerating lands following different successional trajectories. Both species-specific allometric equations and true destructive sampling in the field will allow the calculation of biomass estimates.
LANDSCAPE ANALYSIS: We will use detailed time-series remote sensing imagery of our extensive (20 X 50 km) research landscape in the central Amazon to produce a model of carbon dynamics as a function of identifiable landscape features (e.g., fragment size and shape, and the area and age of secondary forests). The procedure for the satellite analyses will be the following:

41. Register all the thematic mapper images to a high resolution UTM map with precision GPS data from the field
42. Image to image registration will then be performed using the base map as the reference base
43. An unsupervised cluster classification will be run in conjunction with a knowledge-based classifier to classify the 20 x 50 km proposed study area into the 11 categories above
44. The resulting classification will field checked and corrected where necessary for each of the satellite images used in this study, based upon reference data collected in the field using GPS, photographs, field notes, and aerial overflights
45. The resulting classification will be "vectorized" into an ArcInfo coverage and further edited where necessary
46. Additional GIS layers of topography, river courses, roads, and biological information, including biomass estimates for each time frame, will be co-registered with the satellite data and included into the GIS
47. The resulting combination of the satellite classification(s) from 1982-1984-1986-1988-1990-1992-1994-1996 will be used to extrapolate the biological data spatially over the landscape.

Products of Proposed Research

The proposed research will provide the following products within the three years of operation:

18. Estimates of above-ground biomass stocks and their dynamics in primary tropical rainforest, in rainforest patches of varying sizes, and in different types and ages of secondary forests.
19. A spatially explicit model that links temporal changes in the BDFFP landscape to predicted aboveground biomass stocks and their dynamics of above-ground biomass.
20. A working model of biomass dynamics and landscape features, available for testing in other Amazonian landscapes.
21. Training Brazilian graduate students and research professionals (in-country capacity- building).

Research Team Responsibilities

- Claude Gascon: Biomass estimates and GIS Coordination
- Jim Tucker: Remote Sensing imagery processing
- William F. Laurance: Biological Dynamics of Forest Fragments Project, Biomass estimates in forest fragments and continuous forest reserves
- Rita Mesquita: Biomass Dynamics of Regenerating Forests
- G. Bruce Williamson: Biomass Dynamics of Regenerating Forests

Site

Work will be carried out at the INPA reserve site "Biological Dynamics of Forest Fragments Project".

Activities

1980-1996 biomass estimates in forest fragments and forest reserves: June 1998 - June 1999
Field re-census of plots: June 1998 - June 2000
Secondary forest estimates of biomass: June 1998 - June 1999

Last Updated: May 18, 1998

ND-06 Group Augmented Abstract

Nitrogen and Phosphorus Dynamics in Forests and Converted Forest Sites in the Amazon Basin: A Review and Synthesis of Previous Research

Henry Gholz -- School of Forest Resources and Conservation, University of Florida
Fco. Assis Oliveira -- Department of Forestry, Faculdade de Ciências Agrárias do Para (FCAP)
C. Kenneth Smith -- Centre de Recherche en Biologie Forestière, Pavillon Abitibi-Price, Université Laval, Sainte-Foy (Québec), Canada

Objectives

The principal objectives of this proposal are to:

- Review and synthesize previous research that has examined nitrogen (N) and phosphorus (P) pools and cycling patterns in Amazonian forests and cerrado,
- Review and synthesize previous research addressing changes in N and P dynamics caused by conversion of forest and cerrado to other land-uses (e.g., pasture, secondary forest after logging, agroforestry systems, and tree plantations), and
- Outline gaps in present knowledge and suggest future research directions in this area. Over the past thirty years, road building and government-backed colonization schemes in the Amazon Basin have resulted in increases in human population and rising pressures on natural resources.

Concurrent with this modern colonization of the Amazon has been a growing body of knowledge about nutrient dynamics in Amazonian forests and the affects of forest conversion on nutrient storage and cycling. As this body of literature has expanded, it is clear that the compilation and synthesis of results from these studies is essential to provide researchers and research managers with a concise reference to previous work (much of which is available only in Portuguese), identify gaps in knowledge and potential future research directions, as well as provide policy makers, landowners and land managers with information pertinent to the ecological effects of land use changes in the region.

Continuing conversion of forests to other land uses in the Amazon Basin is inevitable, especially in areas that are close to major rivers, highways, or cities. Therefore, it is essential to address the long-term impacts of forest conversion on nutrient pools and cycling rates and patterns to better understand the limits to productivity once forest cover has been removed. Nitrogen (N) and phosphorus (P) are two elements of particular importance, particularly since their availability for plant uptake are thought to limit primary production (or carbon [C] fixation rates) of ecosystems based on the highly weathered Oxisol and Ultisol soils which cover the majority of the Amazon Basin.

We propose to produce at least one co-authored review paper suitable for publication in the journal Ecological Applications; it is not yet clear whether more than one publication will be warranted, although the three project objectives are suitable to this if the volume of the synthesis in the three sub-areas is sufficient. The publication(s) will also be produced in Portuguese for dissemination and use in Brazilian institutions. In addition, we will publish the results, in part or in whole, in NASA/LBA proceedings as appropriate and contribute the results to the NASA/LBA database (LBA-Ecology DIS).

Research Team

This literature review and analysis will be conducted through an international collaboration with researchers from institutions in the U.S., Brazil, and Canada. The three investigators of this project collectively have literature available from a wide range of sources and countries and in several languages. The investigators worked together from 1993-1996 at the Curuá-Una Research Station (100 km east of Santarém, Pará) in a project that examined plant-induced changes of soil nutrient dynamics under native forest and tree plantations under a USDA competitive grant. The proposed project is designed to be completed within one year.

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Last Updated: May 18, 1998

CD-04 Group Augmented Abstract

Measuring the Effects of Logging on the CO_2 and Energy Exchange of a Primary Forest in Tapajos National Forest

Michael L. Goulden -- Department of Earth System Science, University of California, Irvine CA
Humberto Ribeir Rocha -- Universidade de São Paulo

Objectives

We propose to directly measure the effects of selective logging on the exchanges of CO_2 and energy by a primary forest in the Tapajos National Forest (TNF), Pará using continuous, long-term eddy covariance. We will make these measurements, beginning one year before harvest and continuing for five years pending renewal, above a 2 by 5 km commercial cut that has been scheduled for 1999 by the International Tropical Timber Organization (ITTO) and the Brazilian Institute for the Environment and Renewable Resources (IBAMA) with the US Forest Service (USFS) as a technical partner.

We will use the measurements from the year before the cut to determine whether the undisturbed forest was losing or gaining carbon, and also whether the site was comparable to a nearby undisturbed control. We will use the measurements from the four years following the cut to determine how much carbon was lost, and when and if the forest resumed carbon accumulation. We will complement the eddy flux measurements with continuous observations of above- and below-canopy microclimate, soil respiration using automated chambers and individual-tree gas exchange using sap-flow sensors; intermittent measurements of stem respiration using portable chambers and wood increment using dendrometers; and a survey of logging damage, to understand how and why forest photosynthesis and respiration change during logging and recovery.

Table 1: Proposed Measurements

Sensor	Location(s)
Sonic anemometer; Probably Solent Research HS (horizontally symmetrical head)	~65 m *
Eddy flux CO_2-H_2O; LI-6262 on tower	~65 m *
Profile CO_2- H_2O; LI-6262	~8 at .5,1,2,4,10,20,40,65 m *
Wind speed and direction; Cup anemometer and vane	~65 m *
Air temperature; Aspirated and shielded thermocouples	Same as CO_2 profile &
Rainfall; Tipping bucket	Clearing or tower&
Net radiation; REBS Q*7	~65 m *
PPFD; Licor LI-190SB	~65 m *&
Solar radiation; Epply thermopile pyranometer	~65 m*
Soil and biomass temperature	5 soil profiles at 5, 10, 20, 50, 100 cm plus stem and slash #$

Forest floor PPFD; GaAsP photodiodes	5 clusters of 10 sensors #$
Soil heat flux; REBS HFT3	10 cm depth, 10 plates total #$
Soil water; TDR, either multiplexed or stand-alone probes	5 depths through top meter of soil, 10 profiles #$
Throughfall	2 gutters attached to tipping buckets #$
Continuous soil respiration	15 chambers $
Respiration survey; LI-6200	Stem, soil and slash
Dendrometers	100 Trees $
Sap flow; Granier type	30 Trees $

***** Actual height(s) to be determined later.
40% of these instruments will placed at the start of study, and the remaining 60% placed after the cut adjacent to the automated chambers, including 20% in mechanically compacted regions and 20% in uncompacted regions (Tab. 1).
& A backup set of weather sensors will be recorded independently to ensure a continuous record.
$ In undisturbed forest, gaps and gap edges.

Last Updated: May 18, 1998

TG-02 Group Augmented Abstract

Influence of Amazonia Land-use Change on Chemical Constituents in the Atmosphere

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William Baugh -- NCAR
Guy Brasseur -- NCAR
Jim Greenberg -- NCAR
Peter Harley -- NCAR
Lee Klinger -- NCAR
Janne Rinne -- NCAR
Tania Mascarehn Tavares - Universidade Federal do Pará (UFPa)
Perola Vasconcellos -- University of São Paulo
Brad Baker -- University of Colorado
Lee Vierling -- University of Colorado
Oscar Vega Bustillos
Luciana Vanni Gatti

Objectives

We propose to investigate trace gas fluxes and aerosol concentrations and composition in several Amazonian landscapes in order to improve our understanding of how land-use change may alter the chemical composition of the atmosphere. Information to be obtained will be relevant in two LBA-Ecology theme areas: 1) trace gas fluxes and 2) carbon storage and exchange.

We will employ a strategy that integrates field measurements of chemical fluxes, satellite measurements and ground observations of landscape characteristics, and atmospheric chemistry and transport modeling (Note that only field flux measurements are funded through LBA-Ecology). We propose to substantially improve estimates of trace gas fluxes (CO, VOC, O_3, NOx) and aerosol concentrations associated with major Amazonian landscapes and to use a digital geographical information system (GIS) with numerical models of atmospheric chemistry and transport to quantify the impact of land-use change in Amazonia on the chemical composition of the atmosphere.

Trace Gas Fluxes

We propose to characterize trace gas fluxes and aerosol concentrations over a range of landscapes and land-use types and improve our understanding of the surface and chemical sources and sinks of these compounds. We will measure fluxes of CO, NOx and volatile organic compounds (VOC) at four LBA flux towers for a period of 7-10 days each, using a relaxed eddy accumulation (REA) system. Thirty minute integrated air samples associated with up and down eddies will be collected into teflon bags or adsorbent cartridges and analyzed for CO, CH_4, isoprene, monoterpenes, methanol and other oxygenated VOC, and NOx, all of which play a major role in tropospheric photochemistry. If isoprene fluxes are sufficiently large to warrant further study, we have the capability of continuously measuring isoprene flux using eddy covariance techniques with a chemiluminescence fast isoprene analyzer.

In addition to tower REA studies, vertical profiles of chemical species (CO_2, CO, O_3, NOx, VOC) will be measured at several heights between the surface and 2 km above ground level using a tethered balloon sampling system. Fluxes will be estimated using mixed-layer gradient and mass balance techniques.

Organic aerosols play an important role in biogeochemical cycling of a variety of elements, and influence the hydrological cycle and climate through their role as cloud condensation nuclei. Atmospheric aerosol composition will be measured at three tower sites. Fine (<2.0 mm diameter) and coarse (2.0 mm) aerosol fractions will be collected using stacked filter units, and concentrations and size distributions of aerosols will be determined. Trace elemental composition will be determined. Organic acids, nitrate and sulfate, and major anions and cations will be measured in selected samples using ion chromatography.

Trace gas flux estimates will be incorporated into a 3-D atmospheric chemistry and transport model and used to predict the potential impact of land cover change on the chemical composition of the atmosphere. Trace gas flux estimates will be coupled with a 3-D global atmospheric chemistry model, MOZART (Model of Ozone And Related Species in the Troposphere), that will be used to examine the impact of changes in trace gas fluxes on the chemical composition of the troposphere. MOZART is a fully diurnal model that calculates the distribution and time evolution of approximately 50 chemical species from the surface to the upper stratosphere. An explicit goal in the development of MOZART is to provide a modeling tool for assessing how changes in trace gas fluxes, due to land-use modifications, will impact global chemical budgets.

Carbon Storage and Exchange

The major flux of carbon between the atmosphere and the land surface is in the form of CO_2. However, there is a net efflux of carbon from forested ecosystems in the form of trace gases and organic aerosols which is undetected using the proposed eddy covariance CO_2 flux techniques. The contribution of CO and VOC to the net ecosystem exchange of carbon will be quantified at four tower CO_2 flux sites, using the REA system described above.

Research Team Responsibilities

- Alex Guenther: Management and REA and tethered balloon flux measurements
- Paulo Artaxo: Aerosol size distribution and composition
- Brad Baker, University of Colorado: REA flux measurements and oxygenated VOC analysis
- Bill Baugh, NCAR: Landscape characterization and tethered balloon flux measurements
- Guy Brasseur: Atmospheric chemistry and transport modeling
- Ken Davis, University of Minnesota: Mixed-layer gradient flux estimation
- Jim Greenberg: Trace gas analyses and tethered balloon flux measurements
- Peter Harley: REA flux measurements and VOC enclosure flux studies
- Lee Klinger: Landscape characterization and NOx analysis
- Pérola Vasconcellos, University of São Paulo: Ambient VOC and aerosol measurements

Preferred Sites

We hope to make REA trace gas flux measurements from four CO_2 flux towers, representing a range of land-use types, including primary and second-growth forest. Using tethered balloon measurements, we will investigate trace gas fluxes and aerosol concentrations from a minimum of nine landscapes, covering a range of successional stages, and representing both undisturbed ecosystems and landscapes affected by forest conversion. Site selection and the timing of our field deployments will be coordinated with the LBA-Ecology Science team and with other investigators measuring CO_2 and trace gas fluxes.

Last Updated: May 18, 1998

TG-03 Group Augmented Abstract

Characterization of Aerosol Optical Properties and Column Water Vapor for LBA-Ecology

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Paulo Artaxo-- University of São Paulo
Thomas F. Eck -- Raytheon STX, GSFC
Alberto Setzer -- Instituto Nacional de Pesquisas Espaciais-INPE (Brazilian Space Research Institute)
Brian L. Markham -- NASA/Goddard Space Flight Center
Joel S. Schafer -- Raytheon STX, GSFC

Objectives

We propose to characterize aerosol optical properties and column water vapor during the LBA study. Many LBA researchers will be utilizing satellite imagery for large-scale analysis and therefore will require aerosol optical thickness and precipitable water amounts for accurate atmospheric correction algorithms. A year-round network of six ground-based automatic sunphotometers will be established to emphasize the ecological and remote sensing effects of aerosols. These instruments will be collocated with LBA designated tower sites when feasible. It is expected that 3 more instruments will be purchased and contributed by Brazilian researchers and deployed in a wider distribution near the boundaries of the Amazon region. This study will build on NASA's existing global AERONET atmospheric characterization system and the University of São Paulo in-situ aerosol-sampling program. In this manner, comprehensive climatologies of aerosol and water vapor can be developed that encompass both burning and non-burning seasons for the entire Amazon basin. We intend to use this opportunity to investigate the long-term effects of biomass burning on the vegetation and atmosphere of the Amazon basin and the nature of the atmospheric aerosol observed on a year-round basis.

Site Instrumentation

Each LBA site will be instrumented with a Cimel automatic sun/sky scanning spectral radiometer (direct sun and sky radiance measurements), UVB sensor (0.28-0.32 (m), PAR sensor (0.4-0.7 (m), broadband pyranometer (0.28-2.8 m), and satellite transmission equipment. Automated Cimel sunphotometers make direct sun measurements at 8 wavelengths approximately every 15 minutes from which aerosol optical thickness (AOT) at 7 wavelengths, and precipitable water will be derived. Sky radiance almucantar measurements are also performed automatically which are inverted to yield aerosol size distributions and phase functions.

Seasonal Monitoring

We intend to use this opportunity to investigate the long-term effects of biomass burning on the vegetation and atmosphere of the Amazon basin and the nature of the atmospheric aerosol observed on a year-round basis. The broadband radiometers will provide irradiance data in wavebands significant to vegetative production, and allow characterization of aerosol absorption parameters relevant to remote sensing and climate models.

Field Campaigns

During intensive field campaigns, one site will also feature an Optronics spectroradiometer (0.3-0.8 (m) to measure spectral irradiance and a Yankee MFRSR spectral radiometer (diffuse flux component) to further radiative modeling efforts, and a number of handheld sunphotometers will be deployed to better characterize the spatial variability of the atmospheric aerosol. One field campaign per year will be planned and will include measurements during the pre-burning, burning and rainy seasons over 3 years.

Training and Education

Funds will be designated for a Brazilian graduate student from the University of São Paulo to do field work and later, analysis at NASA/GSFC. The focus of the graduate research will be surface sampling of particulates with an emphasis on modeling of nutrient transport (P, S, K and others) and dynamics, including dry deposition mechanisms. Local site managers will be taught to set-up and maintain instrument suites at each deployment site.

The region is already familiar to the authors who operated a network of sunphotometers successfully in the Amazon from 1993-1995, including the SCAR-B campaign. Over this period sites were developed efficiently in the states of Rondônia, Mato Grosso, Tocantins, and others. Brazilian research aircraft will be available at no expense during some field campaigns and will allow us to operate a handheld sunphotometer to assess the vertical distribution of aerosol.

Preferred Sites

Our tentative plans call for the establishment of permanent sites at Santarém, Tefé, Cuiabá, Manaus, Brasilia and Carajas. (Ji Paraná???)

Activities

Assuming prior LBA project approval, we intend to have 2-4 instruments deployed by May 1998 as permanent installations. The remaining instruments would be deployed by ???? January 1999.

Three field campaigns are planned which will coincide with the pre-burning season, burning season, and rainy season over 3 years. The first field campaign would likely occur ?????

Last Updated: May 18, 1998

CD-11 Group Augmented Abstract

Selective Logging, Fire, and Biomass in Amazonia

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Carlos Sousa Jr. - IMAZON
T.A. Stone - WHRC
K.T. Lawrence - WHRC

Objectives

Biomass and rates of disturbance are major factors in determining the net flux of carbon between terrestrial ecosystems and the atmosphere, and neither of them is well known for most of the earth's surface. Satellite data over large areas are beginning to be used systematically to measure rates of two of the most important types of disturbance, deforestation and reforestation, but these are not the only types of disturbance that affect carbon storage. Other examples include selective logging and fire. Logging and subsequent regrowth of forests have contributed more to the net flux of carbon between the atmosphere and temperate zone and boreal forests in recent decades than any other type of land use. In the tropics logging is also becoming increasingly important. According to the FAO/UNEP assessment of tropical forests, about 25% of total area of productive forests have been logged one or more times in the 60-80 years before 1980. The fraction must be considerably greater at present. Thus, deforestation by itself accounts for only a portion of the emissions carbon from land. Furthermore, as rates of deforestation become more accurately measured with satellites, uncertainty in biomass will become the major factor accounting for the remaining uncertainty in estimates of carbon flux. An approach is needed for determining the biomass of terrestrial ecosystems.

LBA Ecology offers an excellent opportunity to obtain spatially detailed estimates of both disturbance and biomass for the same region and time. The work described here will be of value to LBA Ecology in integrating ground measurements of biomass and satellite-derived estimates of disturbance. The spatial data on biomass will help quantify the emissions and sinks of carbon from land management in Amazonia. They should also help interpret direct measurements of CO_2 flux at tower sites. That is, what portion of a measured carbon sink can be explained by recovery from past disturbances, as opposed to other environmental influences?

The larger rationale for the proposal is development of a technique, applicable globally, for determining the dynamics and spatial distribution of biomass. Biomass is continually changing as a result of disturbance and recovery, and the balance determines a major portion of the net flux of carbon between land and atmosphere. An on-going assessment of the distribution of disturbances and stages of recovery would seem to be a necessary part of a scheme for determining changes in terrestrial carbon storage.

Project Goals

1. determination of the rate of carbon accumulation (ha^{-1}) in logged forests;
2. determination of the rate, areal extent, and spatial distribution of selective logging and fire in three forest types within Amazonia;
3. determination of the spatial distribution of forest biomass as a result of selective logging and fire; and
4. determination of the spatial distribution and the net flux of carbon as a result of selective logging and fire.

The work consists of (1) **ground studies** in areas selectively logged and burned, where rates of wood removal, mortality, and rates of forest growth are measured; (2) **satellite data** (Landsat and radar) to determine the rates, areal extent, and spatial distribution of logging and fire in three areas along the arc of deforestation in Amazonia; and (3) **modeling** to determine the spatial distribution (a) of biomass resulting from current and past rates of logging and fire and (b) of the net carbon flux associated with these processes of disturbance and subsequent recovery. The work will concentrate on a few sites. One will serve to develop an approach; two will serve as validation. The goal is to develop an approach robust enough for use throughout Amazonia as extensive satellite data become available for the region.

Study sites

Fieldwork measuring biomass and rates of growth following logging is being conducted around Paragominas. Validation will be attempted at two sites still to be determined, one proposed for southern Para and one for Acre. In addition, extensive survey data from sawmills throughout Brazilian Amazonia have been obtained by Carlos Souza of IMAZON.

Remote sensing

Two spatial scales are being addressed. First, Landsat TM will be used to identify selectively logged areas in northeastern Para through identification of logging scars (areas indicating logging by roads in primary forest and "patios" or clearing for log storage). These scars "disappear" from TM data in about 1 year as a result of the growth of vegetation. Second, the spatial distribution of 2000 sawmills in Para and elsewhere throughout Amazonia will be used to evaluate how readily selective logging can be monitored remotely, how important selective logging is for changes in forest biomass and carbon balance in the region, and the relationship between logging and fire.

Modeling

Extensive data on disturbance (hectares logged and burned) will be used in a model with site-specific data (carbon/hectare) on rates of mortality, decay and regrowth to calculate the releases and accumulations of carbon resulting from logging and fire. The model is a cohort model that tracks the area, age, and biomass of lands subjected to different kinds of disturbance.

Last Updated: June 25, 1998

LC-06 Group Augmented Abstract

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in Amazonia (LBA)

Alfredo Huete -- University of Arizona
Yosio Shimabukuro -- Instituto Nacional de Pesquisas Espaciais-INPE (Brazilian Space Research Institute)
Getulio Batista -- Instituto Nacional de Pesquisas Espaciais-INPE (Brazilian Space Research Institute)
Jose Epiphanio -- Instituto Nacional de Pesquisas Espaciais-INPE (Brazilian Space Research Institute)
Edson Sano -- Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA)
Christopher Justice -- University of Maryland
Jan-Peter Muller -- University College London
Ranga Myneni -- Boston University
Steven Running -- University of Montana
Alan Strahler -- Boston University
John Townshend -- University of Maryland
Eric Vermote -- University of Maryland
Zhengming Wan -- University of California, Santa Barbara
Laerte Ferreira -- University of Arizona

Objectives

The MODIS Instrument Land Science Team (MODLAND) proposes to provide, evaluate, and validate an array of standard data products as tools for moderate resolution land surface monitoring and ecology over Amazonia.

The LBA experiment and sites will enable us to evaluate the quality and performance of our products in conjunction with in-situ measures of various ecological parameters. MODLAND will make available level 2 and level 3 gridded MODIS data products to the LBA-Ecology Science Team so as to maximize data usefulness and evaluation by the broader scientific community. We plan on working over both LBA transects, encompassing dry and wet tropical forests, cerrado, and various classes of land use conversions.

Research Team Responsibilities

- Alfredo Huete: Spectral vegetation indices.
- Chris Justice: fire and thermal anomalies.
- Jan-Peter Muller: albedo and BRDF.
- Ranga Myneni: leaf area index (LAI), fraction of absorbed photosynthetically active radiation (fAPAR).
- Steve Running: net primary production (NPP)
- Yosio Shimabukuro: biophysical products.
- Alan Strahler: BRDF and albedo.
- John Townshend: land cover and land cover change.
- Eric Vermote, University of Maryland: atmospherically-corrected, surface reflectances.
- Zhengming Wan, University of California, Santa Barbara: surface temperature.

The MODIS land discipline group is developing remote sensing algorithms for deriving time-series data products of various terrestrial geophysical parameters, useful to regional-scale ecological studies of Amazonia.

Atmospheric Correction and Surface Reflectance: MODIS will provide atmospherically corrected (Rayleigh, ozone, water, and aerosols) data sets over the LBA sites in bands 1-7, centered at 648 nm, 858 nm, 470 nm, 555 nm, 1240 nm, 1640 nm, and 2130 nm with respective resolutions of 250 m (bands 1,2); and 500 m (bands 3-7).

Land Surface Temperature and Fire Products: MODIS will provide daytime and nighttime LST at 1 km and 5 km spatial resolutions, at daily, 8-day and monthly temporal frequencies. The MODIS fire products will provide information on the distribution of fires and their frequency and timing. The active fire products will be generated shortly after launch (6/98) and the burned area products are planned for release one year later.

Vegetation Indices (Vis) and Biophysical Products: Two vegetation indices will be produced at 16-day and monthly intervals; the standard Normalized Difference Vegetation Index (NDVI) and an Enhanced Vegetation Index (EVI) designed for extended sensitivity into high biomass, chlorophyll-saturated, conditions. A number of vegetation biophysical parameters will be produced to describe vegetation canopy structure (LAI) and the fraction of absorbed photosynthetically active radiation (fPAR). The LAI and fPAR products will be produced at 8- and 16-day intervals. MODIS will also produce a Net Photosynthesis/ Net Primary Productivity product utilizing the spatial and temporal dynamics of the LAI/ FPAR products in conjunction with a BIOME-BGC ecosystem simulation model.

Land Cover and Land Cover Change: MODIS is developing two products, a Land Cover (classification) product that will map the terrestrial surface of the world into land cover classes; and a Land Cover Change product that will detect areas of change and identify the type of change process occurring. The algorithm for mapping global terrestrial land cover will be at a 1 km resolution. The land cover change product will detect areas of change and identify types of change processes as they occur.

Spectral Albedo and BRDF: The MODLAND team will produce a global BRDF product at 1km spatial resolution for the entire terrestrial surface at 16-day intervals, utilizing both MODIS and MISR data sets.

Preferred Site

We plan on validating our products at all LBA sites, particularly in the vicinity of the LBA-towers.

Activities

We plan to begin providing and archiving MODIS imagery of each product in September 1998. Most of our field activities related to validation will be conducted in coordination with the LBA science team and LBA field activities. We plan to participate in joint field activities with the LBA science team once a clear experimental plan is formed.

Last Updated: May 18, 1998

TG-07 Group Augmented Abstract

Soil Biogeochemistry of Carbon, Nutrients, and Trace Gases in the Amazon Region of Brazil: Field Studies and Models of Natural and Managed Conditions

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William de Mello -- Universidade Federal de Fluminense, Niteroi, Rio de Janeiro
Patrick Crill -- University of New Hampshire (UNH)
Changsheng Li -- UNH
Whendee Silver -- University of California
Ed Veldkamp -- University of Goettingen
Brian Brynne -- USDA Forest Service
Peter Czepiel -- UNH
Ali Etebari -- UNH
Don Herman -- University of California
Evilene Lopes -- Universidade Federal de Fluminense, Niteroi, Rio de Janeiro
Robin Martin -- UNH
Megan McGroddy -- University of California
Cindy Mosedale-- UNH
Any Mosedale-- UNH
Jason Neff -- Colorado State University
Maria Rivera -- USDA Forest Service
Mary Sanchez -- USDA Forest Service
Fred Scatena -- USDA Forest Service
Andrea Spangenberg -- University of Goettingen
Ruth Varner -- UNH
Antje Weitz -- UNH

Objectives

We propose studies in three theme areas of LBA Ecology: carbon storage and exchange; nutrient dynamics; and trace gas fluxes. We propose to work in undisturbed and logged forest and in pastures in the area of the Tapajós National Forest south of Santarém, Pará where we will contrast soil biogeochemical processes on sandy Ultisols and clay Oxisols.

CARBON STORAGE AND EXCHANGE. We will measure litter-fall and fine root biomass, productivity, and decomposition on two common soil types in both logged and undisturbed old- growth forest. We will provide a multi-year record of CO_2 exchange between the soil and the atmosphere for old growth forest and logged forests on two soil types, as well as for old and young pastures using different management approaches. For old-growth forest, we will deploy automated soil enclosures to determine the largest component of ecosystem respiration thereby providing a critical check on eddy covariance estimates of carbon exchange.

NUTRIENT DYNAMICS. We will compare nutrient stocks and cycling in litter and roots on two contrasting soils. Analysis of nutrient retranslocation and experimental fertilization of root-ingrowth cores will allow us to identify nutrient limitations.

TRACE GAS FLUXES. We will obtain a continuous multi-year record of soil atmosphere CO_2, N_2O, NO, and CH_4 fluxes from old-growth forest, logged forest, and pasture using automated and manual enclosures. These measurements will be complemented by gas concentration profile measurements obtained continuously from towers for N_2O and CH_4 at 30-minute intervals in both undisturbed and logged forest. Data screened for suitable atmospheric conditions will allow us to estimate ecosystem fluxes for N_2O and CH_4. We will evaluate the linkage between ecosystem productivity and N-oxide emissions in both pastures and forests through measurements and simulations using DNDC.

Our coordinated measurements will link above- and belowground productivity and nutrient cycles to trace gas exchange. Coordinated measurements and experimental manipulations will allow us to gain a mechanistic understanding of the soil processes controlling carbon, nutrient and trace gas dynamics. Measurements at a variety of temporal and spatial scales will be synthesized using the framework of the DNDC biogeochemical model modified for forest conditions. The understanding generated by this effort will be linked to ecosystem productivity, a factor that may aid extrapolation beyond our research site.

Research Team Responsibilities

- Patrick Crill: Trace gas and carbon measurements
- William de Mello: Trace gases, nutrient cycling
- Michael Keller: Trace gases, below-ground carbon cycling
- Changsheng Li: Models of ecosystem production, soil biogeochemistry and trace gases
- Whendee Silver: Below ground carbon and nutrient dynamics
- Edzo Veldkamp: Trace gases, nutrients and productivity in pastures

Preferred Site

We hope to work on old-growth forest sites and logged forest sites in the Tapajós National Forest south of Santarém, Pará and in pasture sites in the surrounding region.

Activities

We are assuming we can begin field activities in mid 1998 and that logging will occur in July-December 1999.

- Litterfall Collection, Undisturbed Forest - June 1998 to Dec. 2000
- Litterfall Collection, Logged Forest - July 1999 to Dec. 2000
- Litter Decomposition Assays - Sept. 1998 to Aug. 2000
- Sequential Root Coring, Undisturbed Forest - June 1998 to May 1999
- Sequential Root Coring, Logged Forest - July 1999 to Dec. 1999
- Trench Plots (Root Decomposition) - Dec. 1999 to June 2000
- Pasture Clipped Plots - June 1998 to May 2000
- Trace Gas, Manual Enclosures (all land uses) - July 1998 to Dec. 2000
- Trace Gas, Automated Enclosures, Undisturbed Forest - August 1998 to Dec. 2000
- Trace Gas, Tower Profiles, Undisturbed Forest - July 1998 to Dec. 2000

Last Updated: May 18, 1998

Radon-222 Tracing of Carbon Exchange and Trace Gas Fluxes in Old Growth and Selectively-Logged Amazônian Forests

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Osvaldo Moraes -- Universidade Federal de Santa Maria
William de Mello -- Universidade Federal Fluminense
Patrick Crill -- University of New Hampshire
Howard Mendlovitz -- UNC

Objectives

We will study the rates and mechanisms of processes controlling carbon exchange and trace gas fluxes at both old growth and selectively-logged forest sites in the Tapajós National Forest and surrounding areas south of Santarém, Pará, Brazil. The work will directly address two theme areas in LBA-Ecology: Carbon Storage and Exchange, and Trace Gas Fluxes. The proposed work can be divided into two primary objectives:

- Quantification of air exchange rates and gas fluxes between old growth and selectively logged forests and overlying atmosphere utilizing continuous, in situ radon-222 measurements
- Comparison of radon-derived exchange rate constants and fluxes with values derived from eddy correlation and flux chamber measurements by collaborating investigators.

Radon-222 measurements in forest canopy air, the atmosphere immediately overlying the canopy, the soil atmosphere and in flux chamber samples will be performed in direct collaboration with long-term tower flux and microclimate observations as well as automatic flux chamber studies of trace gas exchanges by other LBA investigators. The most critical assumption in the use of long-term eddy covariance to determine ecosystem CO_2 balance is that the measurements are not biased from day to night (Goulden et al. 1996). Because net carbon uptake reflects the difference between two larger fluxes, respiratory efflux at night and photosynthetic uptake during the day, a small selective underestimation of flux at night can cause a large overestimation of long-term accumulation. Our radon work will be focused on and fully integrated with related studies at two flux tower sites along the east side of the LBA transect proposed to be established by a team of investigators. One of the towers will be located in undisturbed, old growth forest (Wofsy and others) and the other in an area where selective logging will be carried out during 1998 and 1999 (Goulden and others). The radon measurements, conducted in collaboration with tower studies of heat, momentum, CO_2, H_2O and other gas transport by Wofsy et al., Goulden, Fitzjarrald and Moore, and others, and flux chamber studies by Keller, Crill, Trumbore and others, will provide direct quantification of the physical exchange of CH_4, CO_2, N_2O, and other trace gases between soils, the forest canopy, and the overlying atmosphere in undisturbed versus logged areas. The radon measurements will employ multiple flow-through detectors whose use in continuous tower flux studies has been pioneered by our group. The multiple-detector set has been successfully deployed in tower studies at remote locations in collaboration with other investigators for continuous measurements every 30 minutes for periods of up to 4.5 years and at altitudes above the ground ranging from less than 10 cm to 496 m.

The following scientific questions will be addressed through collaborative efforts with other LBA investigators: What are the rates of gas exchange between forest canopy air and the atmosphere and how do these rates vary on daily and longer term temporal scales? How does vertical gas mixing vary with elevation within the forest canopy? How do episodic events (e.g. gust fronts) affect exchange between the sub-canopy layer and the free troposphere? How does thinning of forest canopy caused by selective logging change the gas exchange rate with the atmosphere and the relative importance of various canopy air ventilation mechanisms? Does canopy structure affect the rate of episodic flushing of the sub-canopy atmosphere?

Canopy/Atmosphere Gas Exchange Processes

Recent eddy correlation studies of carbon exchange over tropical forests suggest that mature tropical evergreen forests may indeed be a significant carbon sink (Grace et al. 1995. The most critical assumption in the use of long-term eddy covariance to determine ecosystem CO_2 balance is that the measurements are not biased from day to night (Goulden et al. 1996). Because net carbon uptake reflects the difference between two larger fluxes, respiratory efflux at night and photosynthetic uptake during the day, a small selective underestimation of flux at night can cause a large overestimation of long-term accumulation. Grace et al. (1995) reported an annual uptake of 1 tC ha-1 that reflected the difference between ~10 tC ha-1 uptake during daytime and ~9 tC ha-1 loss at night. It is troubling that Grace et al's (1995) site was a carbon sink on days with calm nights but not on days with windy nights. Perhaps there is a systematic underestimation of C loss during stable periods particularly at night. This is a methodological concern for all tower-based carbon measurements.

Because most trace gases emitted by the biosphere are either photo-chemically or biologically reactive, they are potentially unsuitable direct tracers for trace gas transport within, out of or into vegetated land surfaces. However, radon-222, a radioactive natural gas, is ideally suited for studies of gas exchange in the tropical forests of Amazônia for the following reasons:

1. it is emitted almost exclusively from the soil
2. it is a chemically inert gas, making it suitable for tracing physical exchange between forests soils, canopies and the overlying atmosphere
3. the only sink for radon is radioactive decay which can be easily quantified using its known decay constant
4. its 3.8 day halflife yields nearly conservative behavior in studies of soil/atmosphere and canopy/atmosphere gas exchange
5. existing technology now allows for continuous, multi-altitude radon activity measurements both within and above the forest canopy.

Trumbore et al. (1990; see equation 1) showed that radon-derived gas exchange rates compared favorably with estimates for CO_2 obtained by eddy correlation techniques (Fan et al., 1990; Fitzjarrald et al., 1990). Radon-222 was shown to have the potential to provide an independent and reliable measure of gas exchange rates between soils, forest canopy and the overlying atmosphere.

Our group pioneered the deployment of continuous tower-based atmospheric radon-222 activity measurements during the 1988 ABLE 3A mission near Bethel, Alaska (Martens et al., 1992; Martens, unpublished data) and began continuous, multi-altitude measurements every 30 minutes at a micrometeorological tower site as part of ABLE 3B in the open-canopy, boreal forests of northern Québec, during the summer of 1990 (Ussler et al., 1994). The rate of gas exchange can be computed using a simple inventory model:

where h is the canopy height, C is the spatial mean trace gas concentration within the canopy, S is the soil flux, k is a canopy gas exchange coefficient, Ct is the concentration of the trace gas in the overlying atmosphere, and P and L are production and loss, respectively of trace gas within the canopy. In practice the term on the left is evaluated by comparing concentration profiles at successive time points. Evapotranspiration is not an important source of radon within the Amazônian or boreal forest canopy, and radioactive decay loss of radon is insignificant as well, so the integral term on the right side of equation 1 is negligible and can be eliminated.

Last Updated: May 18, 1998

ND-08 Group Augmented Abstract

Soil Organic Matter Fluxes in Amazonian Forests: Natural vs. Intensively Managed Systems

Ken McNabb -- Auburn University
Luiz G. da Silva -- Faculdade de Ciências Agrárias do Pará (FCAP)
Graeme Lockaby -- Auburn University

Objectives

We propose to study the carbon dynamics of intensively managed tree plantations and directly compare them to those of adjacent undisturbed primary forest. There are at least four current plantation operations in the Amazon basin and these intensively managed systems are sometimes regarded as a strategy to increase fiber production per unit of land area and relieve pressures for harvesting native forests. There are questions, however, as to how conversion to plantations from primary forest or abandoned agriculture land will modify or restore normal ecological processes, particularly, what is the long term sustainability of these plantation systems? We propose to address this issue by comparing the carbon cycling processes of intensively managed plantations to adjacent undisturbed primary forest. In collaboration with the Agriculture College of the State of Pará, we will make a comparison of soil carbon inputs, soil carbon fractions, and the chemical differences between the soils of these two forest types. We assume that land use conversion will result in significant and measurable changes in the carbon inventory of the site and that a stable level of biologically active soil organic matter is the determining factor in long-term site productivity. We seek to identify those components of the carbon cycle most affected by intensive plantation management.

In relation to the stated objectives of the LBA program, our research (1) addresses a specific data gap, (2) measures changes in carbon cycling caused by a land use conversion in the Amazon, and (3) specifically attempts to address the sustainability of this conversion. This data will be essential to determine the suitability of intensively managed plantations as a viable and acceptable land use option in the Amazon.

Approaches

Two sites will be investigated -- a clay soil and a sandy soil. Eight sample blocks of 10 m radius will be established at each site, 4 in the plantation and 4 in primary undisturbed forests adjacent to the plantation. The following measurements will be made in the 16 blocks.

Soil Carbon Inputs

LITTERFALL will be sampled monthly for 24 months and separated into foliar, stem, and reproductive components. To measure LITTERFALL DECOMPOSITION nylon mesh bags containing litterfall will be placed within each forest type and followed over a 24 month period, initiated twice, once in the dry season and once in the wet season. A similar technique will be used to follow DECOMPOSITION OF STEM LITTER in two diameter classes of small stems; <2.5 cm diameter. And 2.5 - 10 cm diameter LITTER QUALITY will be determined by analysis of C, N, P, lignin, and cellulose contents at 3-month intervals. ROOT BIOMASS will be sampled every other month for 12 months using soil cores. An estimate of COURSE WOODY DEBRIS will be conducted during the dry season.

Soil Carbon Pool

Soil sampling will be done in close proximity to each litter trap by bulking a composite of at least three samples. TOTAL SOIL CARBON will be sampled during both the wet and dry season. LABILE/STABLE C RATIO will be analyzed from both wet and dry season samples using a series of sonication, sieving, and densiometric separations to fractionate various soil organic components including an "enriched labile fraction" hypothesized to be the major organic matter pool depleted by cultivation.

Nutrient Dynamics

Extractable P, K, Al, Mg, Ca, pH, and CEC will be analyzed for soil samples taken during both the wet and dry seasons. Soil bulk densities will be determined for wet season samples at two depths. Total soil N will be sampled along with total soil C. Foliar litter samples will be analyzed at 3 month intervals for C, N, P, lignin, and cellulose contents.

Research Site

We will conduct this study on the property of Jari Cellulose, a private enterprise located on the Jari river, the first south flowing major tributary of the Amazon river. This location offers an exceptionally unique situation to compare natural and artificial systems. The company manages approximately 80,000 ha of plantations which, for the most part, are surrounded and immediately adjacent to primary forest that has no history of human intervention with the possible exception of extractive practices. Auburn University has signed a research agreement with Jari Cellulose and has worked collaboratively with the company in the past.

Schedule

- Litterfall collection April 1998 to April 2000, monthly samples
- Litter quality Three month intervals from July 1998 to April 2000
- Litter decomposition Two initiation points - April 1998 and October 1998, 18 months duration
- Root coring October 1998 to October 1999, monthly
- Coarse Woody Debris October 1998
- Soil N and C October 1998 and April 1999
- Soil chemistry October 1998

- Soil bulk density April 1999

Research Team Responsibilities

- Ken McNabb: Project coordinator, silva-culture and management
- Graeme Lockaby: Soil carbon dynamics, biogeochemistry
- Luiz G. da Silva: Carbon and nutrient cycling

Last Updated: May 18, 1998

LC-07 Group Augmented Abstract

Multi-scale Analysis of Inundation with Microwave and Optical Remote Sensing in the Amazon Basin: Applications to Biogeochemical Measurements and Modeling

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Evlyn Novo -- Instituto Nacional de Pesquisas Espaciais-INPE (Brazilian Space Research Institute)
Maycira Costa -- INPE
Leal Mertes -- UCSB
Laura Hess -- UCSB

Objectives

We propose to conduct a multi-temporal, multi-scale, multi-sensor analysis of inundation and wetland vegetation in the Amazon basin that will be linked to biogeochemical measurement and modeling activities of LBA.

Our proposed remote sensing analyses will include optical (Landsat, AVHRR and EOS sensors), passive microwave (SMMR/SSMI) and active microwave (SIRC, JERS, ERS, and Radarsat) data to determine the temporally varying extent of inundation and associated vegetation. We will (1) provide synoptic, seasonal mapping of inundation and wetland vegetation structure for the Amazon basin; (2) incorporate the inundation and vegetation data into a GIS-based database; and (3) apply results from our analyses of wetland vegetation and inundation to related LBA studies of hydrological, ecological, and biogeochemical processes.

The expected time periods for recording an image useable for inundation analysis with the different remote sensing instruments we propose to employ varies from days to months. Based on an analysis of the spatial and temporal resolutions of the satellite sensors, we have determined that data fusion amongst the instruments will be critical to insure sufficient temporal coverage at the appropriate spatial scales. We anticipate that there will be an inundation-mapping limit for typical rivers with contributing drainage basins on the order of 1000-10,000 km2 when the flood conditions occur only for a week to a month. Individual sites may be mappable above and below this limit, depending on the local geomorphology and inundation hydrology.

We anticipate results of our analyses to be important for LBA activities associated with (1) methane and other trace gas emissions, (2) carbon dynamics of flooded forests, (3) land use on flood plains, (4) regional hydrologic modeling, and (6) detection of seasonal and inter-annual climate variability.

Implementation

Implementation of our activities will be done as follows:
Optical sensing - The most effective technique for tracking the zone of river-water influence, in contrast to local-water influence, on wetland inundation is through the use of optical data of sufficiently fine resolution. We will modify our current method for suspended sediment analysis to incorporate data from the optical instruments expected during LBA, i.e., Landsat 7, MODIS, and AVHRR. The optical image analysis will be limited by access to sufficiently cloud and smoke-free data.
Active microwave sensors- We plan to use a multi-stage, hierarchical, rules-based approach to delineate floodplain inundation and vegetation using a decision-tree model which constructs a binary classification tree by recursively partitioning the training data into increasingly homogeneous subsets. Inundation mapping at a fine scale (12.5 m to 100 m pixel spacing) will be carried out using a combination of JERS (LHH), Radarsat (CHH), and ERS-2 (CVV)

data. All these data will offer multi-temporal coverage of selected regions; only Radarsat's ScanSAR is expected to provide multi-temporal coverage of the whole Amazon basin during LBA.

Passive microwave sensors - Low-resolution sensors, such as the Scanning Multi-channel Microwave Radiometer (SMMR) and the Special Sensor Microwave Imager (SSMI), afford a synoptic view of the Amazon basin that complements finer-resolution SAR and optical data. We have developed linear mixing models that incorporate the observed microwave signature's major end members to estimate fractional inundation area. Data will be obtained as 0.25° x 0.25° grid cells, and modal values for each 2-week period will be used to determine inundation area.

Field studies - Field surveys will be required at key LBA sites and selected wetlands to validate our classifications and maps. These surveys will entail low altitude videography and surface inspections from land and water. Geo-location of flight lines and surface sites will be done with portable GPS units. Further, we will use information obtained from the many hours of low altitude videography and field observations that we have collected previously, as well as from published literature and from personal contacts. To improve correlation between water levels and inundation extent in wetlands distant from major rivers or gauging stations on rivers, we will install automatic water level recorders.

Projected Schedule

During the first year, we will emphasize extension and validation of our microwave and optical classification algorithms and assembly of mutli-temporal data sets from ERS, Radarsat, JERS, Landsat and SSMI acquisitions. During the second and third years, we will emphasize production and distribution of inundation and wetland vegetation maps to relevant LBA projects and for our own complementary analyses.

Last Updated: May 18, 1998

LC-08 Group Augmented Abstract

Modeling the Biogeochemical System of the Terrestrial Amazon: Issues for Sustainability

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Steve Pacala -- Princeton University
Jerry Melillo -- Marine Biological Laboratory (MBL)
Charles Vorosmarty -- University of New Hampshire (UNH)
Bruce Peterson -- MBL
Changsheng Li -- UNH
Steve Frokling -- UNH
Bobby Braswell -- UNH
Ernest Linder -- UNH
Xiangming Xiao -- UNH

Overview

The objective of this research is to understand the interactive effects of changes in land-use and climate on 1) carbon storage and nutrient dynamics, including trace gas fluxes, in terrestrial ecosystems and 2) the prospect for sustainable land-use in Amazonia.

The specific product of the research will be a set of coupled, hierarchically structured models accessible through a common model framework. This framework will provide the means for investigating our principal objectives. We shall consider the LBA region within the context of two broad environmental conditions: 1) natural ecosystems where perturbations in biogeochemical states are driven primarily by natural variability of climate and fire, and 2) disturbance gradients that are induced by human land-use activities and/or human-induced climate change.

We will use our models of terrestrial biogeochemical cycles, vegetation dynamics, hydrology and land-use change. We will concentrate on model improvements to ensure applicability of all models to the LBA study region. The ecosystem and hydrology models will be driven by the physical climate; whereas, the land-use model will be driven by biophysical, ecological, and economic constraints. The linked models will be incorporated into a Geographic

Information systems (GIS) context, accessing numerous data sets from LBA or data layers housed at our institutions. We will evaluate model performance by comparison and field measurements from LBA as well from published data sources. We will use satellite remote sensing analysis as a means to evaluate the spatial and temporal patterns of model performance at the regional scale. Finally, we will apply formal statistical methods to characterize model uncertainty, as we apply this work to the question of the human impacts on the Amazonian landscape.

Change from both natural and anthropogenic sources must be appropriately understood. Therefore, we will focus on three objectives:

- The natural pattern of variability in net primary production, respiration, nutrient availability, and the flux of trace gases between terrestrial ecosystems and the atmosphere
- Human-altered land-cover and ecosystem distribution and condition
- The associated changes in the pattern of net primary production, respiration, nutrient availability, and the flux of trace gases between terrestrial ecosystems and the atmosphere.

The Science Objectives

Our research effort links three Objectives. The First Objective focuses on the biogeochemistry of terrestrial systems under the forcing of natural climate variability. Among the topics of interest are the natural pattern of variability in net primary production, respiration, nutrient availability, and the flux of trace gases between terrestrial (including seasonally flooded) ecosystems and the atmosphere. Soil moisture and inundation are also important components of this research because of their controls on trace gas dynamics. In Objective Two, we address the problem of modeling the transient dynamics of human-altered terrestrial ecosystems, including agricultural systems, stages of succession, and the combined forcing of various land-use and climate change patterns. The Third Objective both supports and synthesizes the preceding Objectives. It provides a Geographical Information System (GIS) framework for model development, evaluation, and application. Within the model evaluation theme we will exploit remote sensing, using AVHRR and when available, MODIS and MISR data from EOS AM-1, as well as formal error analysis based upon spatial-temporal statistical techniques. We will use the linked model to explore impacts of land-use and climate change scenarios on the biogeochemistry of the region.

Key Tools

Amazonia contains some of the most productive ecosystems in the world, experiences notable patterns of climate variability on seasonal to inter-annual time-scales, and is undergoing significant changes in land-use. It is thus a region with important fluxes and changes in fluxes of carbon, nutrients, and water. Regional-scale ecosystem modeling, database development and remote sensing analysis will be important tools for evaluating potential consequences of land-use change on the biogeochemistry in Amazonia. Key themes and tools for our work will include modeling of natural and human-managed ecosystems, remote sensing, GIS analysis, and large database assembly and dissemination.

Analysis of Natural Ecological Systems

We have used the Terrestrial Ecosystem Model/Water Balance Model (TEM/WBM) to explore seasonal and climatic variations in net primary production (NPP), heterotrophic respiration (Rh), and net ecosystem production (NEP) for South America, North America, and the globe. TEM is a process-based ecosystem simulation model that uses spatially referenced information on climate, elevation, soils, and vegetation to make monthly estimates of important carbon and nitrogen fluxes and pool sizes. A key feature of TEM is that the carbon, water, and nitrogen cycles are closely coupled.

In order to address the effect of climate variability and climate change, we are developing a transient version of TEM and have used a preliminary version to explore the response of terrestrial ecosystems to historical changes in atmospheric CO_2 concentration and climate in Amazonia, the conterminous United States, high latitude ecosystems, and the globe (see also DNDC discussion in the next subsection (i.e., III. 2)). Inter-annual variations of modeled NPP in Amazonia were primarily associated with inter-annual variations of precipitation. Inter-annual variations in modeled Rh were smaller and connected mainly with inter-annual variations of temperature. The different transient responses of these two carbon fluxes indicate that even under natural conditions, the region sometimes acts as a sink of atmospheric CO_2, and at other times as a source. Within Amazonia, the spatial distribution of carbon sources and sinks also apparently change from year to year. This behavior appears to be linked to the physical climate through ENSO events.

Our earlier work in Amazonia showed the dependence of NPP on water availability. The capability to model and understand changes in the Amazon regional water system is important to studies of terrestrial productivity, and also the significant effects of floodplain inundation on trace gas emissions.

Studies of Managed and Disturbed Ecosystems

We are currently developing a model for land-cover and land-use change. The model consists of: 1) a land evaluation module that assesses the suitability and availability of land for crops and pasture based on biophysical constraints such as climate, soil and topography, and 2) a land-use module, GEOMOD, for simulating spatial patterns of land-use/land-cover as well as the rates of change from landscape to regional scales based upon biophysical factors and socio- economic factors (e.g., population density, land tenure system, timber price). Algorithms within GEOMOD represent the principles of adjacency, dispersion, regional heterogeneity, relative growth, energy efficiency, and resource quality.

Conversion of land to pasture and cropland has had a significant impact on the biogeochemistry of many areas of Amazonia, and these ecosystems must be included in any regional analysis. The DNDC model can be used to simulate carbon and nutrient biogeochemistry in agro-ecosystems. DNDC has simulated 30 years of pasture biogeochemistry following conversion of forest to pasture. Estimated SOM and N2O fluxes are in general accord with a chronosequence study in Costa Rica and simulation of NO flux from fertilized maize grown on recently cleared land is also in agreement with measurement. DNDC has successfully simulated N2O fluxes and soil organic matter (SOM) dynamics in temperate and subtropical regions. DNDC has been used to simulate N_2O flux from agricultural lands in the U.S., and is currently being used to evaluate N_2O emissions from agricultural lands in China, including wet subtropical areas. Tropical agriculture and pasture simulations with DNDC have been focused on Costa Rica, and will be adapted to the LBA region.

Management of Data and GIS Capabilities

Our NASA EOS-IDS and Hughes Applied Information Systems are collaborative partners in a prototyping project that will provide full GIS capability over the internet and is fully interoperable with NASA's EOS Data and Information System Core System (ECS). One aspect of this effort to provide a means for LBA participants to conduct geo-spatial data searches and queries via the internet. We currently have a very rough prototype (http://www.unh-ecs.sr.unh.edu using a Java client and server, a Spatial Data Engine (SDE/ESRI) client and server, and an Oracle database (which provides access to several data layers including information from the Humid Tropical Forest Inventory Project (HTFIP) which is part of NASA's Landsat Pathfinder Project); additional data layers are available from our EOS-IDS research effort including Hydro-Climatology layers provided by the UNH Global Hydrology Research Group). Recently approved funding through the NASA CAN addressing Federation of the EOSDIS will allow a significant expansion of this capability.

Remote Sensing

Issues related to validating spatial patterns of model predictions have been explored using remote sensing. We examined model results of the Vegetation/Ecosystem Modeling and Analysis Project of net primary productivity (NPP), estimated in the conterminous USA at a spatial resolution of 0.5 by 0.5 degree grids. One goal was to check the realism of the spatial variability of model estimates using long-term monthly mean NDVI for each 0.5x0.5 grid cell, using the fact that NPP and NDVI are linearly related. Correlation for the entire domain were relatively high (R2=0.6-0.7). However, comparison of the mean deviates of both NDVI and simulated NPP (each grid cell value subtracted from the mean of all grid cell values in an ecosystem type) were uncorrelated within biomes. Thus the models appeared to be representing across-biome patterns of NPP, but no conclusion could be made about within-biome variability. This type of analysis is potentially very powerful for evaluating model-predicted NPP.

A remotely sensed vegetation index can also yield insight into patterns of response of ecosystems to climate, providing a means to evaluate model response and model-based hypotheses. We used global AVHRR data and gridded air temperature from the Microwave Sounding Unit to estimate the magnitude of immediate and lagged response to temperature. Patterns of zero-, one-, and two-year lagged responses of NDVI to temperature variability were ecosystem dependent and consistent with the hypothesis that biogeochemical mechanisms play an important role in mediating global relationships between CO_2 and temperature.

We have successfully retrieved canopy biophysical variables, including the fraction of PAR absorbed by the canopy (fAPAR) and albedo, using a radiative transfer model and AVHRR data for a transect in the Central African Republic. Though observations of a single pixel have single sun-sensor geometry, we gathered neighboring pixels in temporally composited scenes, having similar functional ecosystem type, in order to simulate a multiple sampling of geometry within approximately 0.5x0.5 "cells". With the advent of MISR data from EOS AM-1, we expect both improved accuracy and the ability to perform inversions using much smaller spatial windows.

Research Team Responsibilities

- Berrien Moore III: modeling
- Jerry Melillo: Biogeochemistry and terrestrial ecology
- Steve Pacala: Modeling and terrestrial ecology
- Charles Vorosmarty: hydrology and biogeochemical modeling
- Bruce Peterson: hydrology and biogeochemical modeling
- Changsheng Li: transient ecosystems and biogeochemical modeling
- Steve Frokling: trace gases and biogeochemical modeling
- Bobby Braswell: remote sensing and biogeochemical modeling
- Ernest Linder: spatial statistics
- Xiangming Xiao: remote sensing and terrestrial ecosystem modeling

We recognize that this research proposal is ambitious. The effort will draw significant support from our EOS IDS grant and other currently funded activities. Our effort will be supported intellectually primarily by LBA investigators and by other institutions, including the MIT Joint Program on Policy and Global Change, the Oak Ridge National Laboratory DAAC, and the University of Texas (Dr. J. Famiglietti).

Last Updated: May 18, 1998

LC-09 Group Augmented Abstract

Human and Physical Dimensions of Land Use/Cover Change in Amazônia: Forest Regeneration and Landscape Structure

Emilio F. Moran -- Anthropological Center for Training (ACT) and Research on Global Environmental Change, Indiana University
Flavio Ponzoni -- Department of Remote Sensing, Instituto Nacional de Pesquisas Espaciais-INPE (Brazilian Space Research Institute)
Dalton Valeriano -- Department of Remote Sensing, INPE
J. C. Randolph -- National Institute for Global Environmental Change, Indiana University
Eduardo S. Brondizio -- Anthropological Center for Training and Research on Global Environmental Change, Indiana University
Paul Mausel -- Department of Geography and Geology, Indiana State University

Objectives

Building on 25 years of research experience in the Eastern Amazon, this study will focus on advancing our understanding of land use and land cover change. It will develop a Spectral Library that will serve the research community and assist in testing of a new generation of sensors (e.g. TM7). This project will build on a seven-region study, along the LBA transects, supported for the past six years by NSF and NIGEC, and encompassing a sample of 100+ sites. We used a nested geo-referenced approach that included soil analysis, vegetation stand structure and composition, land use histories, institutional analyses, demography of households, and land cover classification using Landsat TM multi-temporal data to understand the rates of growth of secondary vegetation. The seven regions' study provides a wide array of land uses and land cover along an east-to-west transect extending from the Amazon estuary and Bragantina region east of Belém near the Atlantic coast, all the way to the Tapajós/Santarém region. This 160,000 km2 area will be examined for land cover changes and their relation to past patterns of land use for a minimum of no less than 25 years. We propose in this NASA/LBA project to extend this work by:

48. Quantifying ecological thresholds driving structural and functional dynamics (e.g., rates of re-growth and species replacement) of secondary succession areas subjected to different land use histories across the seven study regions;
49. Generating models that incorporate socioeconomic, institutional, and demographic determinants of land use and cover change at a variety of scales;

50. Developing a Spectral Library of land cover classes present that can be applied to previous (MSS and TM5) and forthcoming sensors (TM7) through the integration of vegetation inventories, image calibration, and hyperspectral field assessment;
51. Taking this opportunity to synthesize, model, and share data linking ACT's and INPE's data sets along the LBA eastern transect with work in Rondônia; and
52. Providing hands-on experience to a cohort of Brazilian doctoral students in their work on land use/cover change and the human dimensions of such change in research in the Amazon region, and to provide other opportunities for mid-career training preferentially to colleagues at Amazonian institutions.

This study will provide the research community with a Spectral Library to facilitate inter-image comparisons of land cover classes and land use dynamics at the center of the LBA campaign. Hyperspectral calibration of a range of land covers of interest to LBA, such as mature upland and floodplain forests, stages of secondary successional vegetation, selectively logged forests, pastures, annual and perennial cropped fields, and savannas, will be an important component of this study. Building this Spectral Library is a challenge that we can undertake only because of the comprehensive nature of past geo-referenced field research encompassing physical, biological and social science variables, and because of its spatial distribution over seven different regions that permits scaling from farm/household to regional dimensions of land use and land cover. We proposed studies primarily addressing the theme of land use land cover change and secondarily on carbon storage and exchange.

Field Activities

- Hyperspectral video overflights of study areas; vegetation field inventories and land use histories as scheduled below:
- Summer 1998 Altamira (Lower Xingu, Pará) and Santarém (Middle Amazon Valley, Para)
- Summer 1999 Marajo (Pará), Igarapé Açu (Pará); Tomé Açu (Pará)

Training Activities

- An INPE graduate student will come to ACT each year for one semester. An ACT graduate student will go to INPE one semester in Year Two.
- Mid-career training at ACT for two individuals for one-month each and up to three Brazilian colleagues at Summer Institute each year.

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CD-05 Group Augmented Abstract

The Present and Future Effects of Ground Fires on Forest Carbon Stocks, Metabolism, Hydrology, and Economic Value in Amazonia and Cerrado

Daniel Nepstad -- Woods Hole Research Center (WHRC), IPAM, UFPa
Heloisa Miranda -- Universidade de Brasilia (UnB)
Adriana Moreira -- WHRC
Claudio Reis de Carvalho -- Empresa Brasileira de Pesquisa Agropecuari (EMBRAPA) / Cpatu
Eduardo Maklouf -- EMBRAPA/Cpatu
Antonio Miranda -- UnB
Carlos Klink -- UnB

Objectives

Amazônian forests are burning beneath the canopy. Each year, accidental ground fires burn a forest area that is similar in size to the area that is cleared and burned, with large but poorly understood impacts on carbon stocks, forest metabolism, forest hydrology and the prospect of sustainable forest management. But these ground fires are not included in deforestation estimates. Forest fires have the potential to initiate a positive feedback with local climate, because fire induced reductions in forest evapotranspiration may cause declines in local rainfall, provoking additional burning of forests which are, themselves, more susceptible to fire each time they burn. These fires may be the first step in a process of "savannization", in which recurrent burning favors the replacement of fire-sensitive trees by fire-resistant grasses and thick-barked trees, a process that has already transformed much of the woodland forests of the Brazilian Cerrado, adjacent to Amazônia, into grass-dominated savannas.

In the proposed research, we will contribute to the land-use, carbon stocks and surface water chemistry themes of the LBA-Ecology campaign by investigating forest fire. We will estimate the contribution of anthropogenic forest fires in Amazônia and the Cerrado to fluxes of carbon and water, and to the economic value of these forests, through a combination of field experiments and measurements, landholder surveys, and regional modeling. The proposed research will provide several data sets for the broader LBA campaign. We will use eddy correlation towers to measure net ecosystem fluxes of carbon and water vapor in four Cerrado woodlands with different levels of fire frequency. We will measure the soil water balance to 8 m depth at these Cerrado sites, in two mature forests and one logged forest equipped with towers in Amazônia, and in one logged forest that is experimentally burned. These measurements will allow us to determine the soil layers from which water is being extracted to supply evapotranspiration and to provide an independent estimate of evapotranspiration that will permit interpretation and testing of the tower-based estimates of ET. We will also quantify several components of net primary productivity that must be measured to interpret tower-based measurements of net ecosystem productivity, including fine and coarse root biomass (to 8 meters depth), fine and coarse litterfall, and stemwood increment. Our study will provide land-use history maps for 300 geo-referenced Amazônian properties, stratified by property size and region, including the timing of forest clearing, forest logging, forest burning, and agricultural management practices, and the economic costs and benefits of fire prevention and fire control practices. Finally, we will develop a mechanistic, predictive model that will allow us to estimate the area of Amazônian forest that burns each year, and associated changes in carbon stocks and water flux. This model will allow us to begin to examine the impacts of climate change and land-use policy change on forest fire. Hence, the proposed study has the potential to contribute directly to the LBA goal of promoting sustainable land-use practices.

Summary of Measurements

- NEP, ET: Cerrado sites (Aguas Emendadas, IBCE reserve)
- Litterfall, root biomass, AG biomass, deep soil moisture (ET, drainage): Tapaj6ós, Cerrado Sites, Sao Gabriel de Cachoeira (?), (and, through other projects: Caxiuaña, Rio Branco, Paragominas)
- Flammability: Tapajós, (and, through other projects, Paragominas, Santana de Araguaia, Rio Branco)
- Property surveys of fire history, economic aspects of fire prevention and fire damage: five study regions (Tailândia (e. Para), Mato Grosso, Rondonia, Rio Branco, ??)

Related Projects

- Predicting the fire susceptibility of Amazônian forests. (Nepstad, F. Brown, A. Setzer). Development of a model for Brazilian Amazônia of the rainfall regime at which primary forests become flammable. NASA/MTPE/Teco. 1/97 through 12/99.
- The effects of rainfall exclusion on forest flammability, carbon stocks and water relations of Amazônian forests. (Nepstad, Adriana Moreira, E. Davidson, C. Klink, Claudio Reis de Carvalho, Moacyr Bernadino Dias Filho). Experimental drying of a one-hectare forest plot and pasture plots in Flona Tapajos and Cerrado sites, NSF Ecosystems, 9/97 through 8/'00.
- Modelling the effects of seasonal and inter-annual drought on the flow of water, carbon and nitrogen through Amazônian forests. (Nepstad, E. Davidson, C. Potter, E. Maklouf). Adapting CASA model to Amazônia; incorporating deep soil water uptake. NSF/Teco. 9/95-8/98.

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TG-05 Group Augmented Abstract

Modeling Terrestrial Ecosystem Processes, Carbon Fluxes, and Trace Gas Emissions for Land Cover/Use Types of the Amazon Basin

Christopher Potter -- Ecosystem Science and Technology, NASA Ames Research Center
Claudio J. Reis de Carvalho -- Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA) - Amazonia Ocidental
Reynaldo L. Victoria -- Universidade de São Paulo

Joseph Coughlan -- Ecosystem Science and Technology, NASA Ames Research Center
Susan Alexander -- California State University-Monterey Bay
Steven Klooster -- California State University-Monterey Bay

Objectives

There are few, if any, ecosystem simulation models that have been well validated for scaling up trace gas fluxes across land use patterns in the tropics. The research we propose for LBA-Ecology is to test a series of fundamental process-level hypotheses related to specific land use effects on ecosystem biogeochemistry and trace gas fluxes in the Amazon region. The main tool we will use for these tests is the daily model version of CASA (Carnegie-Ames-Stanford Approach) developed at NASA Ames Research Center (Potter et al., 1997), specifically for Amazon land cover/use types. The modeling tests will be conducted in close collaboration with experimental field studies planned for the LBA intensive research sites. Our ultimate research goal is to validate our model applications for different land uses at LBA sites and to scale-up regionally and dynamically the plant-soil biochemical, hydrologic, and production components of the daily NASA-CASA Amazon version, so as to more closely simulate and predict the inter-annual ecosystem observations from LBA. We propose to take a lead role for LBA-Ecology in organizing comparative modeling studies at LBA intensive study sites, and in developing methods to couple ecosystem models of production and biogeochemistry to simulation models and assessments of land cover change for the Amazon region.

Research at NASA Ames has been supported for the past two years to refine and extrapolate the monthly and daily moisture balance and regional plant production components of our CASA model version for Brazil, through a joint research grant (National Science Foundation-TECO #9524050) with collaborators (D. Nepstad et al.) at Brazil's Instituto de Pesquisa Ambiental da Amazon (IPAM) to study moisture relations in forests of the eastern Amazon. Regional model drivers have been assembled and an Amazon-basin version (8-km spatial resolution) of the NASA-CASA model has been completed under this grant (Potter et al., submitted). Under LBA-Ecology, we now propose to investigate the effects of changing land use in more detail, through relatively high resolution (<1 km2) model applications that focus on ecosystem production, nutrient cycling, and biogenic trace gases (BTG) exchange along important eco-climatic transects and at intensive LBA study site locations. A central working hypothesis for our research is that the quality and supply of decomposing plant material in soil is a major controller of mineralization rates and trace gas flux during and after land use change. Interacting effects of soil moisture holding capacity and canopy water relations must also be tested.

As a second new component of the study, we propose to develop and test methods of scaling up our various cover-type versions of the model to produce regional flux estimates (at 1-km to 8-km grid cell resolution) primarily of CO_2 and N_2O (and secondarily of NO, CH_4, CO, and volatile organic compounds (VOC)) for comparison (validation) with aircraft and tower eddy flux estimates and for input to transport tracer models of the region. Our fundamental working hypothesis is that large-scale conversion from primary forest to pasture and recovering forests represents a substantial and sustained change in the basin-wide emission budgets for trace gases. To address the LBA priority of scaling up flux estimates of CO_2 and N_2O (plus NO, CH_4, CO, and isoprene gases), we will conduct spatial model studies chiefly for upland hydrologic environments. This will require continuous validation of the model structure to represent major changes in soil moisture status, canopy cover, and carbon/nutrient content of vegetation and soil with altered land cover/use, including forest conversion to pasture, selective logging and secondary forest re-growth. We will test land use effects on BTG flues from soils, nutrient mineralization from litter and soil organic matter, nitrification rates, and plant nutrient recycling, with increasing emphasis on phosphorus cycling in degraded areas and feedback to ecosystem production. As we move closer to full regional scaling of simulations in the various land cover type, our focus will be on testing model refinements related to broad scale drivers for rainfall, cloud cover, vegetation types, inundation, and other soil attributes for simulations that include the most current and detailed LBA results for land cover/use change in the Amazon.

Our modeling research results will identify which factors (ecological and anthropogenic) significantly influence key processes that control productivity and biogeochemistry of tropical ecosystems, and have important sources of variability in the spatial or temporal domains of interest in the LBA. Over the course of the project, we will deliver to LBA's data information system (DIS) the research products from our Amazon geographic information system (GIS) analysis, including evaluations of BTG fluxes, evapotranspiration, soil C and N stocks, and mineralization fluxes at a grid resolution of 1-km to 8-km for the entire Brazilian Amazon basin. In addition, we present plans to enhance our ongoing cooperative training component in ecosystem modeling for counterpart scientists and students from Brazil.

Research Team Responsibilities

Principal Investigator:
Christopher Potter -- Overall model development and coordination
Brazilian Collaborator:
Claudio J. Reis de Carvalho --Forest hydrology and radiation balance
EMBRAPA - Amazonia Ocidental
Laboratorio de Ecofisiologia Vegetal
and Instituto de Pesquisa Ambiental da Amazon (IPAM)
Co-Investigators:
Joseph Coughlan -- Forest hydrology and radiation balance model development
Susan Alexander -- Canopy trace gas model development
Steven Klooster -- Ecosystem model programming and scaling
Technicians/Specialists:
Vanessa Brooks (GIS model programming and data assimilation)
Johnson Controls World Services
NASA Ames Research Center
Jennifer Dungan (Geo-statistical model programming and scaling)
Johnson Controls World Services
NASA Ames Research Center

Preferred Sites

Paragominas, Manaus, and Rondônia (TBD)

Activities and Deliverables

Throughout our research period, we will submit (for distribution by the LBA-DIS) written reports (publishable versions to the peer-reviewed literature) and numerous associated data products from the modeling efforts described above.

- Ecosystem Modeling Studies at Intensive Field Sites in the Amazon. Report(s) will evaluate the performance of ecosystem model algorithms at various LBA-Amazon study sites and land use types, with emphasis on hypothesis testing and identification of critical gaps for data input, process calibration, and validation of ecosystem biogeochemistry and BTG fluxes.
- Regional Modeling of Carbon Storage and Trace Gas Fluxes in the Amazon. Report(s) will evaluate temporal and spatial aggregation errors related to requisite data sets across the Amazon region. The report(s) will identify ecosystem locations and climate regimes most strongly affected by temporal-spatial scaling issues and uncertainty. Findings will outline future data requirements for improved regional carbon and nutrient budgets.
- Expected digital products for the Amazon Basin (1- to 8-km) resolution:
    - Soil texture and pH classes *a*
    - Canopy ET fluxes (daily and monthly) *b*
        - Plant and soil CO_2 and CO fluxes (monthly) *b*
        - Soil N_2O and NO fluxes (monthly) *b*
        - Plant VOC fluxes (monthly) *b*
        - Soil N mineralization rates (monthly) *b*
        - Soil C and N storage (both total *a* and labile *b* fractions)

    a Derived from geo-statistical analysis or GIS routines
    b Derived from simulation model output; daily results for transects.

Deliverables from testing the NASA-CASA microclimate framework from a monthly to a daily and hourly time step include 1) expansion of model microclimatic variables by simulating cloud cover, short-wave radiation, and dewpoint, 2) optimization of required model inputs by substitution of observed daily radiation with simulated daily radiation, 3) testing the temporal variability of climate drivers for trace-gas emission algorithms coupled to the NASA-CASA framework.

Last Updated: May 18, 1998

CD-06 Group Augmented Abstract

Carbon and Moisture Fluxes along the LBA Transects: Data Assimilation and Modeling

ND-09 Group Augmented Abstract

Biogeochemical Dynamics in River Corridors of the Amazon Basin and Their Response to Anthropogenic Change

Jeffrey Richey -- University of Washington
Reynaldo Victoria -- Universidade de São Paulo
Victoria Ballester -- Universidade de São Paulo
Niro Higuchi -- Instituto Nacional de Pesquisas da Amazônia (INPA)
John Hedges -- University of Washington
Allan Devol -- University of Washington
Miles Logsdon -- University of Washington
Emilio Mayorga -- University of Washington
Giora Proskowrski -- University of Washington

Objectives

We propose studies in 4 theme areas of LBA Ecology, with a primary emphasis on the dynamics of surface water chemistry, and secondary emphases on nutrient dynamics, trace gas fluxes, and carbon. Our research objectives are to:

- Establish the geographic and geochemical sources of C, N, and P species for river corridors,
- Define the biogeochemical consequences for water chemistry (and to a lesser extent gas emissions) of anthropogenic perturbations against the background of natural environmental variability,
- Determine the downstream fate of sediments, nutrients, and organic matter, as mediated by the transport properties of the river system and the reactivity of the materials themselves.
- Extrapolate these results and to contribute to overall biogeochemical modeling in LBA by assimilating data on carbon, nitrogen, and moisture fluxes from experimental, tower and aircraft databased on the modeling and remote sensing activities of our EOS IDS project.

Research will concentrate in the Rio Ji-paraná basin, and will be extended with more modest measurements of other basins in Rondônia and arrayed along the LBA transects elsewhere in the Amazon (at sites where significant local collaboration is feasible). We will work along land-use and moisture gradients, with the intention of quantifying key fluxes and understanding the underlying dynamics for river corridors.

We will (with final and exact details subject to further negotiations with LBA partners):

53. Develop a variable-scale drainage basin element model for biogeochemical processes which includes water balances and routing (in conjunction with hydrology work elsewhere in LBA). This will require development of multi-scale digital elevation models and spatial data layers (topography, soils, land use) sufficient to evaluate 4 km, 1 km, and ultimately 30 m resolution. The enhanced hydrological models will allow us to implement a more detailed consideration of the mechanistic processes and factors controlling within the CASA modeling environment of the evolution and partitioning of organic matter, nutrients, and trace gases.
54. Establish and operate a distributed sampling network in the Rio Ji-Paraná basin which will allow us to measure the temporal variability in the distributions of water flux and attendant chemical composition at the exit to the basin, then progressively work our way upstream, sampling the diverse sub-regions, approaching the low order streams. To generalize results, we will explore lower resolution field areas elsewhere in Rondônia and in the Amazon.
55. As these sites we will make measurements of hydrological parameters, groundwater and stream chemistry (NO_3, NH_4, PO_4, alkalinity, pH, O_2, particulate and dissolved organic CNP, major anions and cations, and routine stable isotopes, surface area, individual amino acids, individual sugars, and lignin-derived CuO reaction products.), and(funding dependent) gas concentrations and fluxes (CH_4, N_2O, and CO_2). Sources of N_2O through the d15-N and d18O of N_2O, while transformations of ON to NO_3 using d15-N techniques. In-

channel production and mineralization will be investigated with the distributions of dissolved gases (O_2, CO_2, N_2O, CH_4, $18O_2$).

56. Regional extrapolation in the overall context of biogeochemical cycling will be based on time series multispectral image measurements along the LBA transects to validate and determine uncertainties in remote sensing inputs (e.g., FPAR, net solar radiation, temperature, non-photosynthetic vegetation) from image data. These data are used as inputs to our EOS-IDS regional hydrology/biogeochemical cycling model.

Last Updated: May 18, 1998

LC-10 Group Augmented Abstract

Pattern to Process in Amazônia: Measurement and Modeling of the Inter-Annual Dynamics of Deforestation and Regrowth

David L. Skole -- Department of Geography, Michigan State University
Marcos Pedloski --
Marcellus Caldus -- University of São Paulo / Michigan State University
Adilson Serrao -- EMBRAPA/CPTu
Robert T. Walker -- Department of Geography, Florida State University
Charles H. Wood -- Center for Latin American Studies, University of Florida
William A. Salas -- Institute for the Study of Earth, Oceans, and Space, University of New Hampshire

Objectives

This proposal seeks to understand the inter-annual variability in deforestation and abandonment rates in the Brazilian Amazon region. We propose six Tasks, which integrate satellite remote sensing measurements at basin, and site scales field-based case studies at the farm and household scale, and models. We propose to couple our results with other projects and studies under LBA, providing data and models on deforestation rates, its spatial pattern, and re-growth. We pose two questions:

57. Are the inter-annual dynamics and rates of deforestation and abandonment to secondary forest significantly different than the decadal mean values in Amazonia, and can this account for a dampening of the biogenic source of carbon apparent in annual observations of atmospheric carbon dioxide and oxygen?

58. Through the integration of socioeconomic and satellite data and the development of dynamic deforestation models, can we improve our understanding of the dynamics of deforestation and the various controls on rates of deforestation and re-growth?

To answer these questions we will measure inter-annual rates of deforestation and re-growth for the whole basin using stratified sampling methods with Landsat data. We then establish intensive case studies using multi-temporal (annual) satellite data at specific sites to estimate transition dynamics and transition probabilities for secondary growth turnover in simple LUCC models. Finally we Conduct field-based case study analyses of the decision-making processes for farmers and other land-managers, using key informant surveys and models. This is new work, not currently funded by another source, but we collaborate with other funded projects to meet our objectives.

Research Team Responsibilities

- David L. Skole: Lead the entire investigation
- Robert T. Walker: Process-level controls on deforestation and re-growth due to land management/use at field and household level
- Alfredo K.O. Homma: In country coordination
- Charles H. Wood: Collaborator under Walker

- William A. Salas: Case Studies of annual dynamics of deforestation and re-growth

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CD-07 Group Augmented Abstract

High Resolution Carbon Exchange over Large-Scale Amazônia Based on Modeling and GOES Satellite-Derived Radiation Inputs

Eric Smith -- Florida State University
Jiujing Gu -- Florida State University
John Norman -- University of Wisconsin
Harry Cooper -- Florida State University
Peter Snyder -- University of Wisconsin

Objectives

Photosynthesis and respiration by vegetation and soil play a vital role in the carbon cycle over the rain forest in the Amazônia region. Among various key factors in determining these physiological processes by models are photosynthetically active radiation (PAR), and the canopy and soil temperatures (Tc , Ts). For example, it has been suggested that the CO_2 uptake rates over the Amazon forest may be highly sensitive to radiation and temperature. That the system may change from a sink to a source in response to reduced radiation levels due to cloud cover or an average temperature rise of a degree or less. However, our knowledge of the space-time distribution of PAR and Tc is too incomplete to facilitate large-scale comprehensive modeling studies. The data currently available for Amazônia come from only a few sites, and thus past studies of this kind have been restricted to specific time periods and areas. Moreover, extrapolation of datasets to larger spatial scales and longer time periods may not be appropriate because of discontinuous processes controlling PAR and Tc.

Scientific Objectives

This proposal address these concerns with the following four main scientific objectives:

59. retrieval of the surface radiation budget over the large-scale Amazon basin, including retrieval of PAR, Tc, and Ts, based on GOES-8 satellite measurements;
60. examination of net CO_2 exchange between the atmosphere and the soil-forest ecosystem as a function of land type and land-use based on a biosphere model forced with satellite-derived inputs;
61. analysis of the basin-wide spatial and temporal variability of net CO_2 exchange;
62. Quantification of the effects of distribution of environmental variables such as cloudiness, boundary layer thermodynamics, and aerosol concentration on scaling up both in space and time of seasonal and basin-wide CO_2 exchange.

Approach

Retrieval of the surface total solar fluxes and PAR fluxes is to be carried out with a physical algorithm designed for GOES satellite measurements which has been successfully applied to the BOREAS project. For the long-wave fluxes, we will use a new algorithm based on the idea of energy balance for a surface layer. To obtain the canopy and soil temperatures, we begin by retrieving surface radiometric skin temperature (Trs) from the GOES split window channels, then employ an optimization procedure in conjunction with the biosphere model to separate the Tc and Ts temperatures. The resulting datasets including the SRB fluxes, PAR, Trs, Tc, Ts, and the CO_2 flux will be calculated over a 4 x 4-km grid at 30-minute time resolution. With these space and time resolutions, the datasets are expected to play a vital role in various modeling studies to be undertaken within the LBA-Ecology project.

The CO_2 flux modeling is to be accomplished by forcing the biosphere model with the above-derived radiation and temperature variables. The model will incorporate one of the following physiological parameterizations, depending on available data: (1) scaling leaf photosynthesis, respiration, and stomatal conductance to the canopy if canopy-level data are not available; (2) canopy-level parameterization based on light-use-efficiency if canopy-level data are available. The main results from the modeling efforts will be detailed time series of the various CO_2 flux components at the high space-time resolutions.

Scientific Importance

This will be the first detailed, quantitative study of CO_2 exchange over large-scale Amazônia. The study is designed to take advantage of recent advances in physiological and biosphere modeling, and the intrinsic high space-time resolution capabilities of the GOES Imager. One of the motivations of this study is to determine the space-time sampling requirements needed to obtain representative estimates of CO_2 exchange over the Amazon basin. This process variability is controlled by the heterogeneity of land cover, changing environmental factors in the planetary boundary layer, and the highly variable cloud systems and aerosol plumes affecting tropical South America.

It is our hypothesis that representative carbon budgets cannot be obtained by monitoring at a limited number of point sites, even if all major land classifications are sampled, because the processes controlling boundary layer thermodynamics and cloud formation are not ergodic and thus require frequent sampling to ensure accurate integration. Currently, we do not quantitatively understand the sources of carbon budget variability in the rain forest, nor the best strategy to integrate up to basin scales from the limited amount of information currently on hand. In conducting this study over the large-scale basin, we expect to determine the major factors controlling CO_2 flux exchange variability, which will help shed light on how changing climatic conditions would be expected to alter carbon sequestering and its release in the Amazônia rain forest.

Value of Results to LBA-Ecology

The results are expected to contribute to the LBA-Ecology scientific goals in several ways. With high space-time resolution CO_2 fluxes, we shall be able to estimate the net CO_2 fixed by different land covers on different time scales by integrating various components of the CO_2 fluxes in time at selected sites. Similarly, by integrating the CO_2 fluxes in space, we shall be able to estimate contributions by different land covers to basin-wide carbon accumulation. In addition, with the high resolution radiation and temperature inputs, which are greatly affected by cloudiness, boundary layer temperature-moisture, and aerosol concentration, we will be able to quantify the effects of the variation of these environmental variables on scaling up to seasonal and basin-wide scales.

Research Team Responsibilities

- **Eric Smith**: Radiative Transfer, Biosphere Modeling, Surface Radiation Budget, Atmospheric Remote Sensing in Optical-Infrared-Microwave Spectrums, Analysis of Large Satellite Datasets
- **Jiujing Gu**: SRB/PAR Retrieval from GOES/AVHRR Satellite Measurements, Solar Radiative Transfer, Satellite Data Management
- **John Norman**: Biophysical Research on Plants and Environment, Carbon Budget, Biosphere Modeling, Surface Remote Sensing in Optical-Infrared Spectrums
- **Harry Cooper**: Biosphere Modeling, Cloud Processes, Mesoscale Modeling

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Last Updated: May 18, 1998

TG-08 Group Augmented Abstract

Trace Gas Fluxes Associated with Land-Cover and Land-Use Changes in the Brazilian Amazon Basin

Paul A. Steudler-- The Ecosystems Center, Marine Biological Laboratory (MBL)
Carlos C. Cerri-- Centro de Energia Nuclear na Agricultura (CENA)
Jerry M. Melillo-- The Ecosystems Center, MBL
Christopher Neill-- The Ecosystems Center, MBL

Objectives

The objectives of this project are to measure changes in key soil processes and the fluxes of CO_2, N_2O, and NO associated with the conversion of tropical rainforest to pasture in Rondônia. In sum, these measurements are intended to provide a comprehensive quantitative picture of the nature of surface soil element stocks, C and nutrient dynamics, and trace gas fluxes between soils and the atmosphere during the entire sequence of land-use change from the initial cutting and burning of native forest, through planting and establishment of pasture grass and ending with very old continuously-pastured land. These results will also be used to develop process-based trace gas models.

This research is organized around three questions:

- **Question 1: How does the conversion of forest to pasture affect soil physical and chemical properties, C, N and P stocks, and C and N cycling rates?**
- **Question 2: How does the conversion of forest to pasture affect the fluxes of CO_2, N_2O and NO between the soil and the atmosphere, and what are the major controls of these fluxes?**
- **Question 3: What is the importance of land-use change to trace gas fluxes on the scale of Rondônia and of the entire Brazilian Amazon Basin?**

We have examined changes in the stocks of C, N and P and the cycling rates of C and N in pastures three years old and older at Nova Vida. While this work documents changes to biogeochemical processes over a wide range of pasture ages, it does not capture the potentially large and important changes that occur in the early stages of forest clearing and pasture establishment. To understand the dynamics of biogeochemical cycles immediately after deforestation, our efforts related to this question will focus on the study of changes in C, N and P stocks and C and N cycling rates in a newly created pasture at Fazenda Nova Vida.

We will also measure the fluxes of N_2O and NO in the forests and in the established pastures along our existing sequences. Concurrent measurements of N_2O, NO and controlling factors will enable as to predict the ratios of the production of these important gases under a variety of environmental conditions. We will also perform plot-level manipulations in a forest and two pastures to examine controls on trace gas fluxes. We will manipulate soil moisture and fertilize with N and P in a forest site and pastures cleared in 1987 and 1972. These manipulations designed to study the degree to which soil moisture and N and P availability control the fluxes of N_2O and NO. The understanding of controls of trace gas fluxes gained from these experiments will be used by us to construct predictive models that will allow extrapolation to other soil types, climate regimes and management regimes.

We will use ecosystem models of biogeochemical processes coupled with geographically referenced information on land-cover and land-use change to estimate the changes in C and N stocks and the fluxes of CO_2, N_2O and NO throughout the Brazilian Amazon for the past two decades. Extant biogeochemistry models will be parameterized by us using results of our own work in Brazil and the research of others working in Brazil and throughout the new-world tropics. The biogeochemistry models will be of two types: response function models such as MBL/TCM and processes-based models such as DNDC. We will then couple these models with information organized in our geographic information system (GIS) on soils, climate and ecosystem state (land cover and land use) to estimate gas fluxes.

Contribution to LBA-Ecology

This study will contribute in several ways to ongoing interdisciplinary efforts to understand the current biogeochemical functioning of Amazonia, the influence of the dominant land-use change on that functioning and how these changes will ultimately influence the interactions between Amazonia and the Earth's biogeochemical cycles and climate. First, information derived from field measurements of soil carbon balance and the fluxes of greenhouse gases (N_2O, CO_2) following deforestation will provide an invaluable empirical base from which to build Basin-wide assessments of changes to carbon stocks and trace gas emissions through the use of GIS and other tools for regional extrapolation. Second, new information on NO fluxes will contribute to understanding of the current contribution of intact Amazonian forest to the regulation of atmospheric oxidant balance and its potential for alteration following land cover conversion. Third, improved understanding of nutrient and moisture controls on soil trace gas fluxes will permit construction of process-based models that will improve the ability to predict future consequences of land-use changes, land management practices and altered climate. Not only will we contribute information to LBA but also measurements made by others in LBA will serve as a check on our scaling attempts

Research Team Responsibilities

Paul A. Steudler: trace gas fluxes and modeling
Jerry M. Melillo: regional and basin wide modeling
Christopher Neill: nutrient cycling and C and N stocks
Diana Garcia, Post Doctoral: P cycling and stocks and trace gas fluxes
Carlos C. Cerri: C and N stocks and regional C modeling

Activities

Our research will be conducted at Fazenda Nova Vida in Rondônia where we have been working for the past six years.
Nutrient cycling and trace gas measurements along forest-pasture sequences: 1998-1999
Nutrient cycling and trace gas measurements in fertilized and irrigated plots: 1998-2000
Trace gas model development and regional extrapolation: 1999-2000
Regional and Basin wide modeling: 1999-2000

Last Updated: June 3, 1998

TG-06 Group Augmented Abstract

Vertical Profiles of Carbon Dioxide and Other Trace Gas Species Over the Amazon Basin Using Small Aircraft

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P. Artaxo -- Instituto de Fisica da Universidade de São Paulo (IF/USP)
P. S. Bakwin -- NOAA/CMDL

Objectives

We will carry out, at two sites and during the full multi-year period of LBA, weekly measurements of the vertical profiles of several trace gas species and isotope ratios. We will measure the mixing ratios of CO_2, CO, CH_4, N_2O, H_2 and SF_6, and the $^{13}C/^{12}C$ and $^{18}O/^{16}O$ isotopic ratios in CO_2, in 20 flask samples collected automatically during each flight up to an altitude of 3-5 km or more, depending on the altitude ceiling of available local aircraft for hire. As they are available, we will use NASA, INPE or other research aircraft to obtain samples at higher altitudes. Flask samples will be collected over the ocean NE of Belem and over a forest area in the central Amazon basin in order to quantify the change in trace gas mixing ratios and isotopic composition during the transit of air across the basin. The central basin site will be coordinated with one of the flux tower clusters. Other areas will be sampled on a campaign basis, and coordinated with other LBA investigations, primarily to examine the isotopic signature of CO_2 exchange in other ecosystem types. The flasks will be analyzed in our laboratory in Boulder using existing equipment, and all species mixing ratios and isotopic ratios will be firmly tied to internationally accepted calibration scales. The observations will constitute the first multi-year time series of CO_2, CH_4 and N_2O mixing ratios and CO_2 isotopic composition over the Amazon region. Measurements of SF_6 will give a sensitive indicator for penetration of northern hemisphere air into the study area. The data will provide an important constraint for regional and global models of these trace gases, and an independent estimate of regional exchange for validation of scaling of observations from the flux towers to the whole LBA study area. In addition, the payload requirements for our equipment are modest, approximately 60 kg, and our aircraft flights could be a useful resource for other investigators in LBA.

Last Updated: May 18, 1998

ND-10 Group Augmented Abstract

An Integrated Use of Experimental, Modeling and Remote Sensing Techniques to Study Carbon and Nutrient Dynamics During Tropical Land Use Change

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Mercedes Bustamante- University of Brasilia
Gina Cardinot- University of Brasilia
Cory Cleveland- University of Colorado
Jason Neff- Stanford University

This project began prior to the LBA call for proposals, and is funded by NASA's New Investigator Program. Thus, this abstract will be slightly different than most of the others in that we will briefly outline relevant work already accomplished as well as list our future plans. The majority of our work is in the Santarem/Tapajos region (lat/long: 3S, 56W).

Objectives

The overall objectives of this project can be divided into three main areas:
1) Process-level measurements of biogeochemical patterns following conversion of moist tropical forest to pasture, with an emphasis on changes in P, Ca, Mg, K and their effects on C and N cycles. This work is being done along two pasture-age gradients south of Santarem; one on high clay soils (avg. 54% clay), and one on extremely sandy soils (avg. 92% sand).
2) Remote sensing- Biogeochemistry links, including (a) regionalization of pasture biogeochemical information using high-spatial resolution Landsat TM data and a radiative transfer inverse modeling technique, (b) analysis of seasonal trends in pasture vs. forest canopy greenness and energy absorption using an AVHRR spectral unmixing method, and (c) analysis of the biotic response of the uncleared areas of the Amazon Basin to inter-annual climate variability.
3) Estimates of how tropical land conversion affects the use of atmospheric $^{13}CO_2$ data as a tracer of regional fluxes in the global carbon cycle.

Brief Synopsis of Progress to Date

As mentioned above, we are focusing on the Santarem region, where we have established several sites that comprise pasture age gradients (2-15 years old) on two soil types (sand and clay). Data from these sites show a suite of biogeochemical changes as pastures age, including substantial losses of soil organic matter, N, P, Ca, Mg and K. In addition, while both soils demonstrate these declines, there are significant differences at every pasture age between the soil types. Preliminary foliar data from pasture grasses suggest that the strongest increases in nutrient limitation are in N, P and Ca.
Early results from radiative transfer (RT) model inversions using both field-collected spectral data and satellite optical data suggest that changes in productivity (NPP) and biomass which accompany changes in biogeochemistry can be resolved at regional scales using satellite data, thereby allowing much more meaningful spatial and temporal analyses of land use effects on carbon and nutrient cycles than can be approached using standard remote sensing classification or ground techniques alone. We are also finishing a basin-level analysis of inter-annual variability in NPP, linked to precipitation anomalies associated with the El Nino Southern Oscillation (ENSO). These results show significant inter-annual variability of Amazon moist forest physiology and carbon uptake which, when

combined with carbon efflux data from land cover / land use change analyses by other groups, may change our perspective on spatial and temporal variation in sources and sinks of CO_2.

Finally, we have used data and modeled simulations of changes in ^{13}C of respired CO_2 following deforestation, along with continental-scale databases of land cover change for the last 30 years (eg. Houghton's data), to estimate the current imbalance in atmosphere-biosphere exchange of ^{13}C that is due to tropical land conversion. We have then made preliminary calculations of how this imbalance, or "dis-equilibrium", affects atmospheric ^{13}C-based estimates of global terrestrial vs. oceanic net fluxes of CO_2 (cf. Ciais et al 1995, Francey et al. 1995). Our preliminary results suggest that this land-use dis-equilibrium must be taken into account, as incorporation of our estimate into the Francey et al (1995) analysis changed their partitioning of terrestrial vs. oceanic exchange by an average of 0.65 GtC/yr. This change manifests itself primarily as an increase in CO_2 uptake by terrestrial ecosystems in the tropics.

Current Activities (Spring 98)

1) Continued work on the biogeochemistry of our pasture sites, including Hedley-style fractionations of soil P, potential N mineralization, and foliar lignin analyses.
2) RT inversions of TM data to see if the limited spectral information in the latter can still provide information on changes in biomass and NPP with pasture age
3) Regional estimates of pasture LAI and NPP at TM scale-resolution for the Santarem/Tapajos region

Future Plans (Summer 98 - Spring 00)

Pasture Biogeochemistry:

We are planning at least 3 more trips to the Tapajos sites; these trips will be timed so that we can collect data in both dry and wet seasons. We plan to supplement the data we have on soil and foliar C, N, P and base cation content with repeated measurements of several more dynamic variables, including using ion exchange resin bags to measure availability of N, P and base cations in both wet and dry seasons in all pasture sites. We will also measure dissolved organic nitrogen (DON) and phosphorus (DOP) in soil solution in both wet and dry seasons, and plan to install several Prenart tension lysimeters in a subset of the pastures as a pilot experiment to look at leachate losses of all the above elements. In addition, we are planning a series of small-scale fertilization experiments in forest and pasture sites to investigate microbial nutrient limitation. Finally, we are planning a number of isotopic measurements aimed at understanding rates of organic matter turnover and loss in these pastures. In collaboration with Jason Neff (Stanford Univ.), we will measure ^{13}C and ^{14}C of bulk soil carbon, fractionated SOM, soil CO_2, and dissolved organic carbon (DOC) in forests and pastures on both soil types. We will also repeat the foliar analyses we've already done in the wet season, and will measure aboveground biomass of pasture grasses in both wet and dry seasons.

Remote Sensing:

In addition to continued work on the projects outlined above, we are actively planning to use MODIS, MISR and ASTER data when it becomes available in 1999. We intend to spectrally unmix the MODIS data to recover pasture and forest reflectance signatures. Due to the daily 1km-resolution coverage of MODIS, we think that the analyses of land-cover phenology and NPP will be greatly improved using this instrument. MISR data will aid in determining the degree of aerosol and water vapor contamination which has been a constant problem with the currently available AVHRR data. Using both MODIS and MISR, we will improve estimates of greenness, canopy energy absorption, and NPP. Concurrent AVHRR data may also allow for retrocalibration of at least the more recent AVHRR data.

ASTER data will be used in conjunction with Landsat 7 data to continue the inverse modeling--biogeochemistry effort. Both of these datasets will be critical for spectral unmixing of the MODIS data. Unmixed MODIS data also has the potential to be used for RT inverse modeling, particularly due to its SWIR (1300-2500 nm) spectral coverage (Asner et al. in review). The SWIR range contains significant information on bare soil extent and canopy litter fraction (Asner 1998), and we are working as part of the Schimel EOS IDS group to develop the algorithms needed to retrieve critical pasture canopy characteristics using unmixed MODIS data.

Last Updated: June 3, 1998

CD-08 Group Augmented Abstract

Carbon Dynamics in Vegetation and Soils along the Eastern LBA Transect

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Plínio Camargo -- Centro de Energia Nuclear (CENA), University of São Paulo, Piracicaba, Brazil
Luiz Martinelli -- Centro de Energia Nuclear (CENA), University of São Paulo, Piracicaba, Brazil
John Southon -- Center for Accelerator Mass Spectrometry, LLNL, Livermore, CA, USA
Jeff Chambers -- University of California, Santa Barbara, CA, USA

Objectives

We will combine radiocarbon with more traditional measures of C inventory and fluxes to study the stocks, allocation and turnover of carbon at intensive study sites along the eastern LBA transect. In spite of their importance to regional and global C budgets, the understanding of C residence times in vegetation, detritus and soils is very poor in tropical ecosystems. In particular, the roles of woody biomass and detritus, which contain large amounts of C with decadal or longer turnover times, need to be better quantified and are amenable to study with radiocarbon. We will focus on 5 specific components of stand-level C cycling at several intensive study sites:

63. quantifying of C uptake rates in growing trees using bomb radiocarbon in concert with diameter increment measurements to determine the average rate (and variability) of tree growth over the past 3 decades
64. determining age demographics of tree populations, using radiocarbon to determine tree age
65. assessing the rate of production and decomposition of dead wood debris using permanent plot and decomposition rate experiments
66. using radiocarbon in fractionated organic matter together with measures of C fluxes and stocks in soils to determine the amount and turnover time of C in fast-cycling and mineral-stabilized organic matter in soils
67. Using ^{14}C measurements in respired CO_2, microbial biomass, and soil organic matter to partition total soil CO_2 efflux into components from metabolic respiration and heterotrophic decomposition.

We will combine these with measurements of litterfall, root dynamics and CO_2 fluxes by other groups to produce site-specific models of C cycling for comparison with eddy correlation measurements of net ecosystem production (NEP).

Our data will provide process-level understanding needed to apportion eddy correlation measurements of whole-canopy net CO_2 flux into above- and below- ground components and to predict what factors may cause inter-annual variability in net C balance. Our studies of tree age demographics will scale this understanding to larger areas, and help determine the best way to extrapolate NEP measurements in space and in time. At the global scale, our measurements of the time lag between C uptake by photosynthesis and loss by decomposition are needed to test ecosystem C models. Additionally, our work with tree demographics will have implications for forestry management, since our preliminary results show some large, economically valuable trees are very old (1000 years).

Last Updated: May 18, 1998

CD-09 Group Augmented Abstract

A Modeling Synthesis of the Impacts of Tropical Forest Conversion on Carbon Fluxes and Storage, and on Nutrient Dynamics in Amazônia.

Mathew Williams -- Marine Biological Laboratory (MBL)
Yosio Edemir Shimabokuro -- Instituto Nacional de Pesquisas Espaciais-INPE (Brazilian Space Research Institute)
Silvana Amaral --
Edward Rastetter -- MBL

Objectives

Our objectives are to quantify and improve our understanding of the changes in C storage, C exchange, and nutrient dynamics in response to human-induced environmental change in Amazônia. We will address these goals using models of canopy gas-exchange and ecosystem biogeochemistry. These models will allow us to use existing information and information collected during the intensive field studies to generate regional extrapolations, thus creating linkages in LBA between the specific point studies and the remotely sensed data.

We will use a hierarchy of models to scale in space from point to region and in time from hours to decades.

68. At the finest scale we will employ a process-based multi-layer canopy, soil-plant-atmosphere model (SPA) that predicts hourly gross photosynthesis and transpiration. This model is parameterized with fine-scale measurements of canopy structure and meteorology, and can be tested against independently collected tower eddy covariance flux measurements. We will also develop a transect version of the model to generate predictions of gas exchange along an aircraft flight path. The transect runs will necessarily be parameterized with less detailed data, and will allow us to investigate the effects of any simplifying assumptions on model efficacy.
69. At the next coarser scale, we will use a simpler, aggregated model of daily whole-canopy carbon © fixation and transpiration. This model is derived wholly from the process-based model, capturing its aggregated behavior, while operating with daily input and at significantly higher computing speeds. This aggregated model serves two purposes. Firstly, it can be employed within a gridded GIS database, so that we can derive regional estimates of C and energy fluxes under specified land-use and climate change scenarios. Secondly, it can be inserted into our ecosystem biogeochemistry model as a validated photosynthesis/transpiration component.
70. The third model, of ecosystem biogeochemistry (MBL-GEM), will be used to examine the coupling between nutrient dynamics and longer-term C storage and exchange. Our primary goal will be to test whether we can predict the long-term responses of biomass and soil organic matter to land-use change using chronosequence data for validation. This model will also be coupled with a GIS-database model to generate regional extrapolations. In this instance our predictions of regionally varying biomass and leaf area can be tested against remotely sensed data as a further test.

The proposed work will represent a significant step toward an understanding of Amazônia for three important reasons. Firstly, by identifying key functional differences in canopy gas exchange characteristics our soil-plant-atmosphere model will help to develop effective inter-site comparisons. Secondly, our models represent a logistically effective means for generating linkages among components of LBA, particularly in terms of linking the point measurements of towers with remotely-sensed regional data-sets. Our aggregation protocols will help to generate coarser-scaled predictions, with more modest data requirements, better suited for extrapolation. Thirdly, we will integrate the understanding derived from tower-based flux measurements into our ecosystem biogeochemical models. Understanding the linkages between C and nutrient cycles is crucial for developing long-term predictions of the response of biomass and soil organic matter to land-use and climate change.

We hope to work closely with those teams making eddy flux measurements, both from towers and aircraft. We are also interested in collaborating with groups developing regional data sets of land-cover, vegetation type and climate variables. We are searching for a Brazilian or South American collaborator to work with us on model parameterization, validation, analysis, and extrapolation.

Last Updated: May 18, 1998

CD-10 Group Augmented Abstract

Net Ecosystem Exchange of CO_2 and H_2O from primary tropical forest in Central Amazônia

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Paulo Artaxo-- University of São Paulo
J. Wm. Munger -- Harvard University
Carol C. Barford -- Harvard University

Bruce C. Daube -- Harvard University
John C. Lin -- Harvard University
Scott Saleska -- Harvard University
Shawn Urbanski -- Harvard University
Allison Dunn -- Harvard University
John Budney -- Harvard University
Alfram V. Bright -- Harvard University
Elizabeth Pyle -- Harvard University

Objectives

We plan measurements of net ecosystem exchange (NEE) and concentrations of CO_2 and H_2O using eddy correlation methods for 3-5 years at a primary forest site 110 km south of Santarém (Tapajós National Forest) in central Amazônia, and measurements of CO_2 and other greenhouse gases at a remote coastal site near Natal. Installation will be in the latter part of 1998 or early 1999, depending on infrastructure and preparation of equipment.

We will collaborate with Dr. V. Kirchhoff to help install and operate a long-term coastal site for observations of important trace gases, starting with CO_2.

We plan to support the observations of aerosol and other atmospheric components by Dr. P. Artaxo, however the funding status of this effort is not presently clear.
The objectives of the measurements will be:

71. Define the experimental protocols needed to measure accurately seasonal and annual net fluxes of CO_2, H_2O, and energy at a primary forest in the Tapajós region of Amazônia;
72. Define the net source or sink of CO_2 from the undisturbed forest;
73. Determine the variations of net exchange of CO_2 seasonally and inter-annually, and define the response of carbon sequestration in the system to climatic and other environmental variables;
74. Provide the experimental control for interpretation of the results obtained at a harvested site (proposed by Goulden, Keller) by recording the CO_2 exchange at a nearby undisturbed site;
75. Provide the flux and gradient measurements for CO_2, sensible heat and momentum needed to define the flux of N_2O, CH_4, and mineral elements from sub-canopy concentration changes or from above-canopy gradient measurements of these species;
76. Determine CO_2 boundary layer concentrations at mid-continent and coastal sites to test models.

Value to LBA

The proposed work focuses on defining the "undisturbed state" of the primary tropical forest, a requirement "to fill the most critical of gaps and/or to gain the most leverage on major scientific uncertainties" (NRA-97-MTPE-02). Studies of this type were specifically requested for LBA: ("Continuous observations of a core set of measurements (e.g., CO_2 fluxes, trace gas fluxes, trace gas concentrations, micrometeorological conditions, radiation, aerosols) made at the primary field sites over a period of 3-5 years".

Approach

Fluxes of momentum, CO_2, H_2O, sensible heat, net radiation, and PAR, atmospheric and soil profiles of temperature, CO_2 and H_2O, and wind profiles will be measured continuously using automated instruments on a 65 meter tower. Fluxes will be measured using eddy correlation, with an infrared gas analyzer (closed-path) for CO_2 and H_2O mounted on the tower near the sonic anemometer. The data will be analyzed to determine net exchange of CO_2 and H_2O on hourly, daily, seasonal, and annual time scales. Environmental regulation of variations in net uptake will be quantitatively elucidated by measuring the response of the system to climatic variations and by comparison between flux measurements and ecological observations.

Site

The measurements will be made from a 65 m tall, small-cross-section tower of the type used to support radio antennas (Rohn 45G, Peoria IL), selected to minimize wind distortion and possible heating artifacts, placing the sensor well above the tallest emergent trees. The data acquisition system and most instruments and will be housed in a climate controlled hut 15-30 m west of the tower base, accessible by a dirt road. The CO_2-H_2O sensor will be placed close to the sonic anemometer near the top of the tower to keep tubing short.

The site is in a protected primary forest reserve at km 117 south of Santarem (IBAMA station S 03o 21.357' W 54o 56.959' in the Floresta Nacional do Tapajos. This site is extremely flat, an extensive planalto that drops about 30m to the level of the Tapajos river 10-15 km to the west. Soils are uniform yellow oxisols similar to soils at the site to be cut, which lies 30 km to the north. The nearest secondary road is 5 km to the east and the nearest urban area is 100 km to the North (Santarem); otherwise the area is quite isolated.

Tower Measurements

Table 1 shows the measurements planned for the site in this and in collaborative studies. Eddy fluxes of sensible heat, latent heat, CO_2, and momentum will measured at 65 m on the tower. The mixing ratios of CO_2 and H_2O will be monitored by sampling 6 to 8 standard liter/min (slpm) from an inlet located directly behind the vertical axis of the anemometer into a CO_2/H_2O infrared gas analyzer (IRGA; Model 6262, LiCor, Lincoln NE). Errors due to separation of the inlet from the anemometer should be small (1 to 2%, Lee and Black 1994). Wind and temperature will be measured with a 3-axis sonic anemometer pointed into the dominant wind direction (east)

Table 1. Tapajos Forest Measurements

Sensor	inlet/instrument alt(s)	determined quantity (data rate)
Sonic Anemometers	65m (3-axis), 6 lvls(2 axis)	u,v,w,T Fmom, Fheat (10 Hz, 30-min avg.)
high-speed CO_2-H_2O (IR-Absorbance)	65m	CO_2 and H_2O fluxes (30-min avg.)
slow CO_2-H_2O (IR Absorbance)	8-10 levels	CO_2, H_2O vertical profiles (2 /hour)
Thermistors, thin-film capacitors	5-6 levels	T and R.H. profiles (5,60-min avg.)
Thermistors	2 cm (6 rep), 20cm, 50cm	soil temperatures (5,60-min avg.)
Photosynthetically Active Radiation	65,24,2 m	(5 min avg.)
Net radiometer	65m	radiant heat flux (5,60-min Avg.)

Special note: spares for key equipment
The budget justification includes spare units for key hardware including sonic anemometers, CO_2-H_2O IRGA, etc., to be purchased just prior to deployment to Brazil. It is expected that equipment cannot be imported in passengers' baggage. Therefore, if a failure occurs, a spare must be present on site, otherwise a hiatus in the measurements as long as 6-8 weeks might be incurred. Such long data gaps would clearly impact the goals of this experiment.

Relationship with Other Experiments

The experiment will be closely coordinated with three other LBA projects:
M. Keller: Our flux measurements will help extend the spatial (canopy) and temporal (years) scales, and provide a quantitative framework, for integrating biogeochemical measurements to the ecosystem function.
Crill, Silver,and Li and Goulden plan to work at a flux tower on a nearby primary forest that will be commercially harvested during the observations. Our measurements at an uncut site nearby will provide the control for this experiment, determining changes in carbon storage and ecological parameters in the absence of disturbance.
We plan to combine our data with observations of canopy/atmosphere interchange and energy balance by Fitzjarrald, Moore, to help define the tower footprint and to wring out systematic errors from the observations.
Collaboration is expected also with Martens (^{222}Rn) and Trumbore and Crill. ($^{13}C/^{12}C$ isotopic ratios and turnover rates of soil organic matter and wood.

Last Updated: May 18, 1998

ND-07 Group Augmented Abstract

Impacts of Land Use Change on Nutrient and Carbon Cycles and Trace Gas Exchange in Soils of Savannas of Central Brazil

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Mercedes M.C. Bustamante -- Departamento de Ecologia, Universidade de Brasilia
Marirosa Molina -- USEPA
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Objectives

The proposed studies will focus on the effects of fire and land use change on the composition and persistence of litter and soil organic carbon and nitrogen and related changes in the soil-atmosphere fluxes of carbon dioxide, carbon monoxide, nitrous oxide, and nitric oxide. The studies are proposed for a range of cerrado types and agroecosystems in the area surrounding Brasilia. We will quantify rates of carbon and nutrient cycling and characterize SOM at sites ranging from undisturbed cerrado to burned cerrado to agroecosystems. These experiments will include measurements of the carbon and nitrogen content and stable isotope ratios of the litter and SOM isolated by size and physical fractionation. The lignin content and concentrations of UV-absorbing compounds of the litter will also be measured. To determine the size and diversity of the soil microbial community at the sites, we will measure the amount and composition of biomarker compounds in the litter and SOM, particularly phosopholipid ester-linked fatty acids (PLFA) and ergosterol. For ecosystems that have undergone a vegetation change (e.g., from C_3 dominated closed canopy cerrado to C_4 pasture) we will measure the carbon isotopic composition of individual PLFAs to indicate the source(s) of carbon being actively metabolized by the microbial community. To provide data and relationships needed for regional trace gas models, we will measure soil-atmosphere fluxes of trace carbon and nitrogen gases (CO_2, CO, N_2O NO) under various natural (e.g. along transects) and manipulated conditions. Ancillary data relevant to these studies will also be obtained, including changes in soil temperature, moisture, and incident solar radiation that accompany land use change and subsequent agricultural uses of the cleared land. Limited manipulations will be conducted during the dry season at the cleared sites, e.g. pasture, to measure the effects of solar UV-B exclusion on fluxes of the trace gases from the surface litter and dead grasses.

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